Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

PRICE 50 CENTS

OCTOBER 1955

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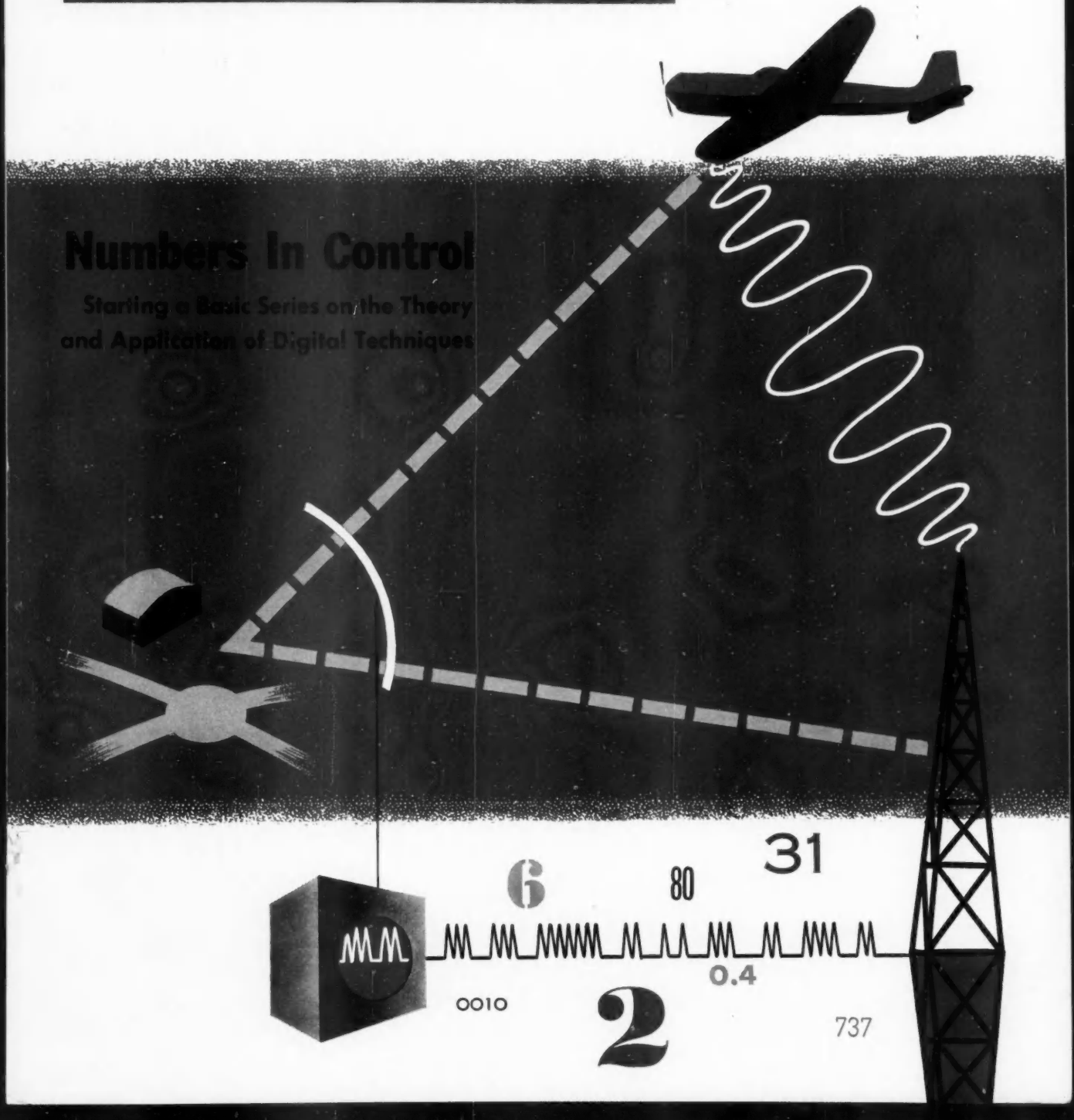
Starting a Basic Series on the Theory and Application of Digital Techniques



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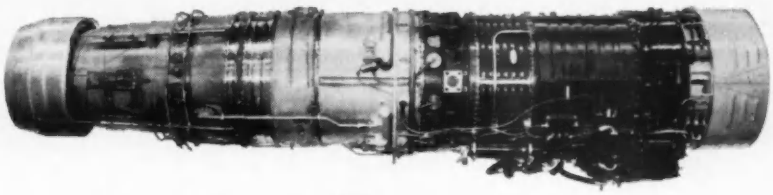
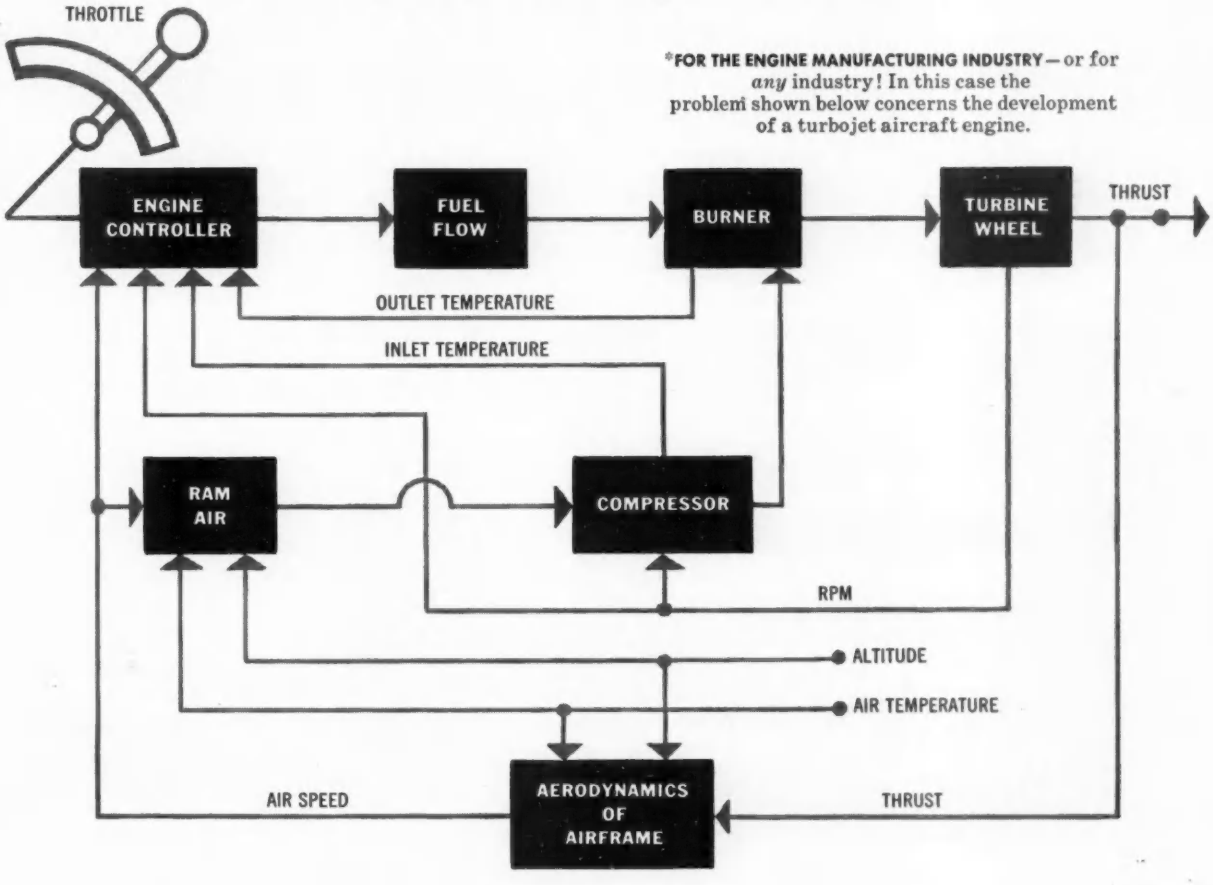


*solves control problems**



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Control ENGINEERING

OCTOBER 1955

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

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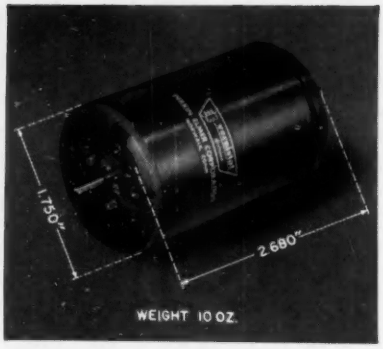

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SHOPTALK

DIGITS, Digits, digits . . .

About two years ago, when CtE was still a gleam in the eyes of a group of editors, something formidable hit the control field. Digits. From aircraft to alchemy, digital techniques (DT's) started to infiltrate automatic control. When our journal first went to press a year later, DT's were still Big News. But the excitement over something new was changing into an anxious search by engineers for theory and facts on just how digits could be put to work in control. Last October By Ledgerwood decided to do something about it. He visualized two series of articles (25 altogether) on the basic theory and the working facts about digital hardware and systems. Pinpointing four top men for each topic, By tied available authors down by letters and trips. How successful was his vision? Turn to page 69 in this issue for the first article on The Basic Digital Series, two months from now begin The Application Series, and in December, 1956, we'll give you a final in the course.

TOOLS ON TOOLS OF THE TRADE

When Bill Vannah keynoted the recent Systems Engineering Symposium at Purdue (see What's New, page 40) he reviewed some of the tools with which control engineers now ply their trade. Samples: frequency response; graphical analysis; analog synthesis. Bill has made sure that our past issues cover these well. But this month we do some cascading. Two ways to use the frequency response tool are explored on pages 56 and 60. And to top it off, one method uses graphical analysis, the other, an analog computer.

RAISING A JOLLY ROGER

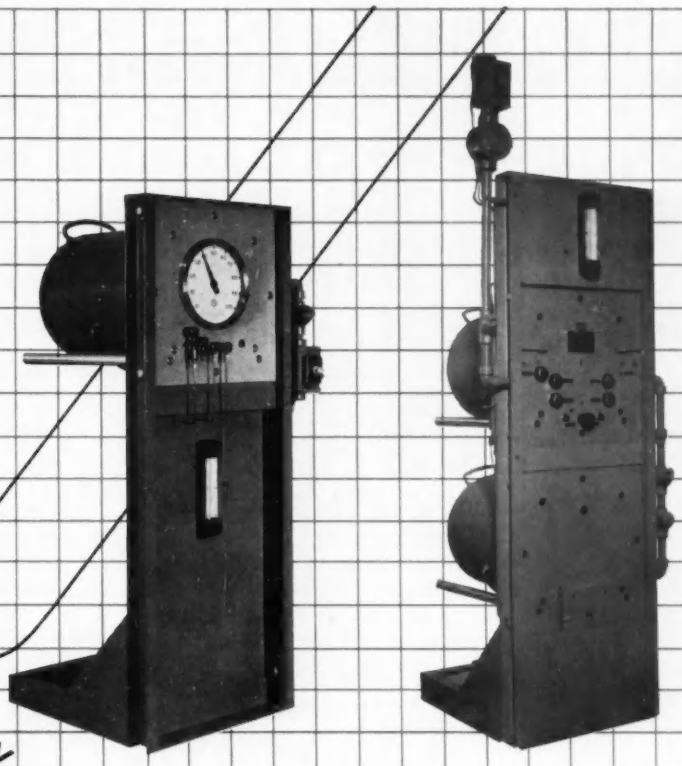
It's not there. But the name Roger Wollstadt deserves to fly high on our masthead. Now a soph at MIT, Roger signed on for a tour of duty with us this past summer. Our original idea was to have an extra pair of legs and hands around the office. But we hadn't reckoned on Roger's head —which met each crisis like a veteran. Our thanks, Roger. We'll hold a berth for you.

Peering over Warren Kayes, Roger spots an error in vector analysis that could have embarrassed a good CtE author

throughput up

quality up

costs down



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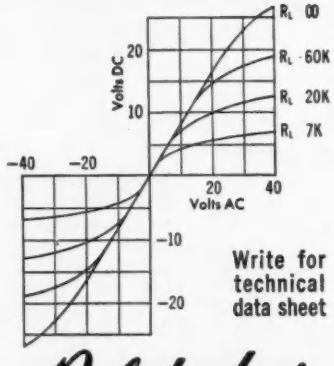

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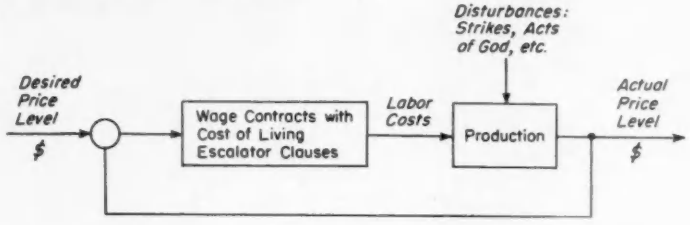
FEEDBACK

WHAT—AGAIN?

Still another look to stabilizing the economy



To the Editor—

It all depends on your viewpoint. Let's consider Mr. Cross's diagram (reprinted above) and the editor's comment in the July issue, page 6. With the usual assumptions as to the nature of cost-of-living contracts and net production costs, the transfer function of each block is positive and the loop will certainly be regenerative. To add further complications, the loop gain is approximately unity.

Problem: Make the feedback negative.

One solution has been provided by the editors: change cost-of-living contracts so that wages drop as prices tend to increase.

An alternate solution would operate on the second block by reducing production costs as prices tend to increase. The writers submit that this

• • •

PROBLEM FORUM

October's prize problem

Here is a reader who would like to avail himself of the unique accumulation of experience represented in our readership. Send in your solutions to his problem; they're worth cash. And submit your own problems. The more basic they are, the more attention they will get from those who attend our forum every month.

To the Editor—

How can I convert the output from a strain gage transducer (4 active gages connected as a Wheatstone bridge) to a proportional frequency? The output of the bridge is 0-30 mvac approximately. Desired frequency band is 500-6,000 cps. The signal is to be recorded on magnetic tape as a frequency signal proportional to torque. The curve of frequency vs. torque must be linear within 1-2 per cent of full scale. The tape is to be replayed through a servomechanism which controls the torque developed through a dynamometer.

Jack W. Schmidt
Trans. Exp. Test Dept.,
Allison Div.,
General Motors Corp.,
Indianapolis, Ind.

OCTOBER 1955 Control Engineering VOL. 2, NO. 10

Published monthly by the McGraw-Hill Publishing Co., Inc., Executive, Editorial, Advertising and Subscription Offices: McGraw-Hill Building, 330 West 42nd Street, N. Y. 36, N. Y. Publication Office, 99-129 North Broadway, Albany 1, N. Y.; entered as second class matter at the Post Office at Albany, N. Y. Donald C. McGraw, president; Paul Montgomery, executive vice-president; Joseph A. Gerardi, vice-president and treasurer; John J. Cooke, secretary; Nelson Bond, executive vice-president, Publication Division. Ralph B. Smith, vice-president and editorial director; J. E. Blackburn, Jr., vice-president and circulation director; Joseph H. Allen, advertising director. FOR SUBSCRIPTIONS, write to: Control Engineering-Subscription Service, 330 West 42nd Street, New York 36, N. Y. Orders must indicate company and position. Allow one month for change of address. Single copies 50¢. United States and possessions: $3 for one year, $4 for two years, $5 for three years. Canada: $4 for one year, $6 for two years, $8 for three years. Latin America: $10 for one year, $16 for two years, $20 for three years. Other countries: $15 for one year, $25 for two years, $30 for three years. Printed in U.S.A.

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latter method has a number of significant advantages:

1. In any feedback system, sensitivity to disturbances introduced at any point within the loop is reduced by putting as much of the available loop gain as possible *before* the disturbance. Applied to Mr. Cross's diagram, this means that sensitivity to strikes, acts of God, etc., can be reduced by making the [wage versus cost-of-living] gain large, at the expense of the [selling price versus cost] gain. This, however, introduces the delicate question of cutting profits. Point 2 shows why this is not really as bad as it may appear.
2. The loop is actually non-linear in its nature. That is, the price-level versus cost ratio depends in an indirect manner on the wage level. When profits are cut, the following may reasonably be expected to occur:
   a) Prices fall
   b) Demand is stimulated by lower prices
   c) Increased sales produce increased profits

Thus, a cut in per-unit profit may have no, or possibly even a beneficial, effect on the overall profit. Of course, this analysis neglects such things as market saturation or jump function requirements in plant overhead. Nevertheless, the point we wish to offer for consideration seems adequately outlined.

Herman I. Jacobowitz
William E. Woods
Philadelphia, Pa.

This goes to show that there is no "best" solution, although there is an optimum one at a given time and place. Any other possible solutions? —Ed.

Nihil novi, except response

To the Editor—

Nihil novi: the installation in Tokyo described by Mr. Sadahiko Araki on page 95 of your July issue, is in every aspect similar to the control setup in Tertre, Belgium, that I designed for the Junkers Co. in Dessau and installed in Tertre for S. A. Carbonization Centrale in 1930.

The problem consisted of controlling the Btu value of gas mixture supplied to two pipe lines, one to Brussels at 4,250 Kcal/m³ and one to Mons at 4,500 Kcal/m³. This gas was composed of a 7,000 to 8,000 Kcal. gas from a Claude-Process ammonia synthesis plant plus a 4,000 to 5,000 Kcal. gas from a Semet-Solvay battery. In case of an excess of Btu's a Morgan

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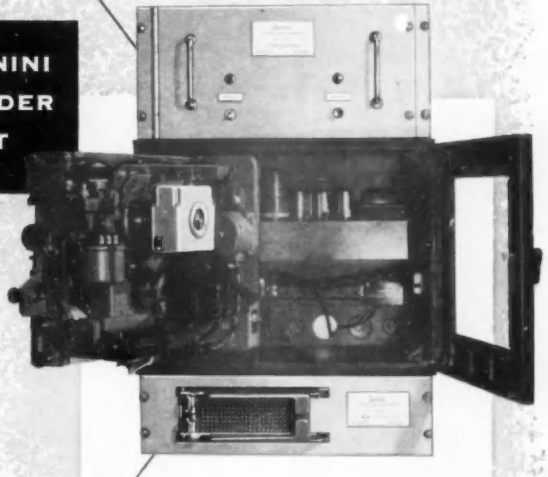

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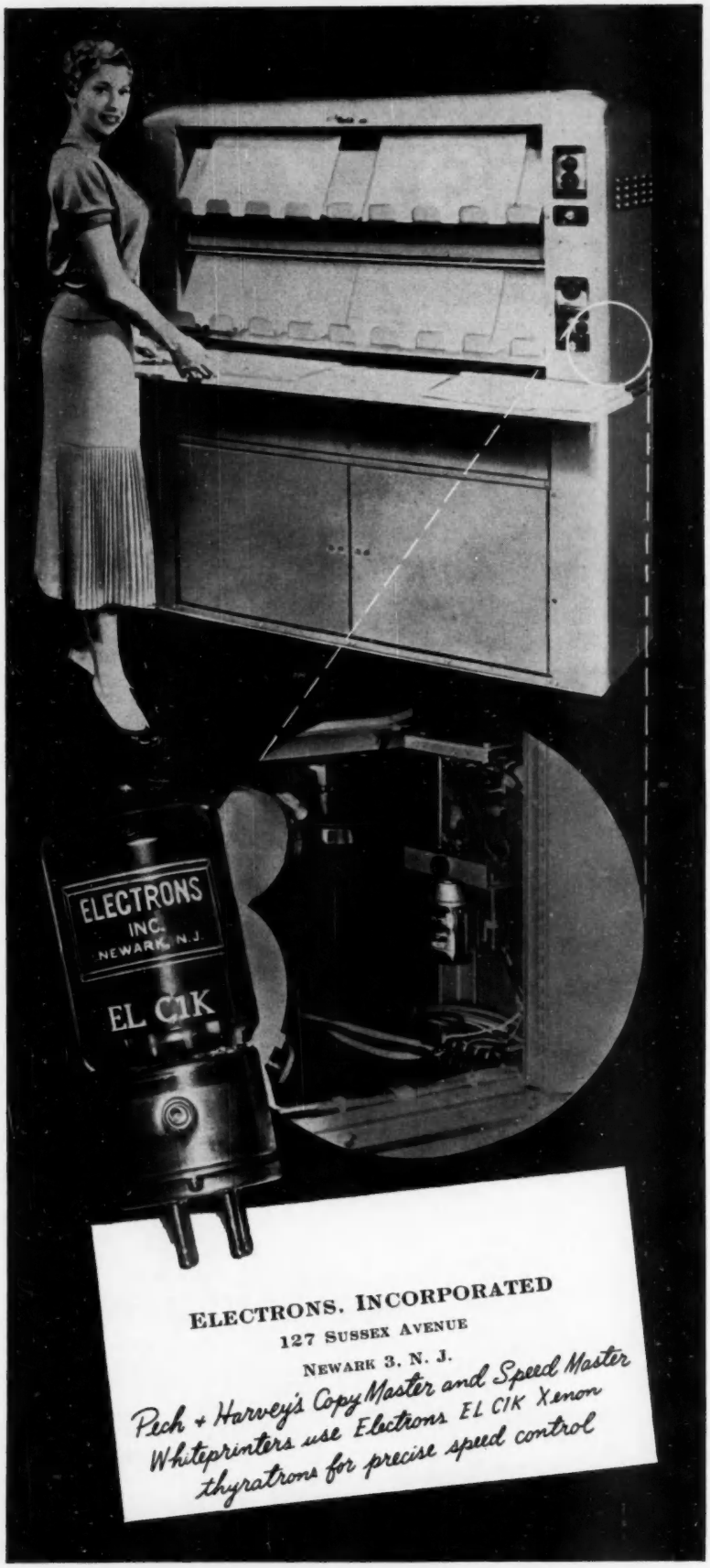

FEEDBACK

1,800 Kcal. generator stood by.

The two Junkers Calorimeters used for this purpose had a considerable lag and have been entirely redesigned to meet the "Distrigaz" Pipeline Co. specification of ± 50 Kcal/m^3.

It is known to the writer that for this particular control purpose a Bunsen-flame sensing device is actually employed in Germany with practically no transmission lag, so that calorimetric errors are largely compensated by speed of response.

Max Studley
Application Engineer
Philadelphia, Pa.

Author rebuts and adds . . .

To the Editor—

I greatly appreciate Dr. Shearer's comments (page 9, August issue) on my article Pneumatic Servomechanisms, (page 65, June issue). It is of course quite true that the components of pneumatic systems are more complex than represented in the article, so that the dynamic properties of the air motor developed in the article are necessarily only approximate, as was indicated. The field of high dynamic performance pneumatic systems has been so neglected in the literature that it was believed that the elementary linear treatment employed would provide useful data and stimulate further work in the field.

In addition to the leaky open-center characteristics of the valve cited by Dr. Shearer, there are other phenomena and problems that need further consideration:

1. The motor itself is a non-linear element whose differential dynamic characteristics depend upon the nominal center of position.
2. The effects of air transmission—and supply-line components.
3. The effects of reducing air stored at high pressure.
4. Better specific methods for improving stability, schemes that avoid the space requirements of the restriction-side-chamber combinations described in the article, schemes that are more sophisticated than the brute force procedure of adding a viscous damper to the piston shaft.

In summary it seems worthwhile repeating our theme—pneumatic servos are capable of high power, high dynamic performance, an area in which they have not been exploited

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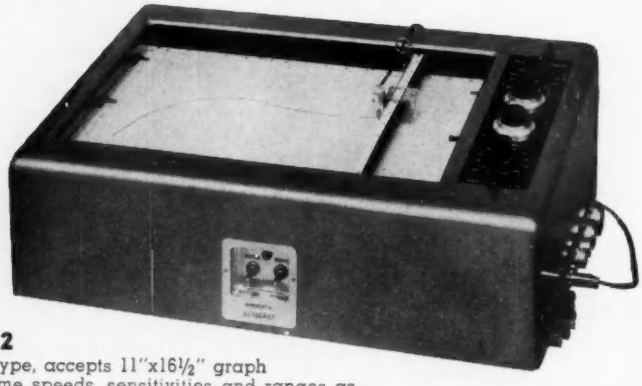
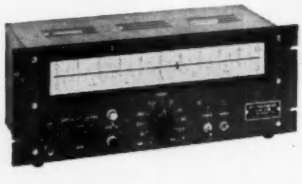
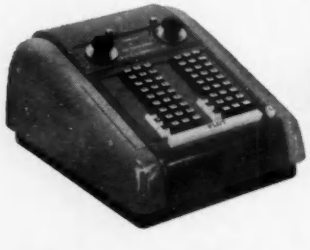


MODEL 2
Flat bed type, accepts 11"x16½" graph paper; same speeds, sensitivities and ranges as MODEL 1; zero set anywhere on paper plus one full scale length of zero-offset; inputs provided for analog recording, point plotting from digital sources, and curve following for computer or data reduction use.



MODEL 20 DC VOLTMETER is a servo-actuated, fast, accurate and sensitive instrument. Has large, easy-to-read scale for general laboratory use where ranges from 3 millivolts to 300 volts are desired. For data handling it is furnished with a built-in Coleman digitizer and delivers digital output for operation of printers, typewriters, tape or card punches, etc.

MODEL 30 CARD TRANSLATOR converts information from punched cards into point form for automatic plotting. Handles up to 50 cards per minute, 10 to 200 counts per inch. Plugs directly into MODEL 2 recorder, controls both card reader and recorder for completely automatic operation.



MODEL 40 KEYBOARD provides a convenient means for plotting large amounts of tabular data in point-curve form. Self-contained voltage source together with full three column keyboard in both X and Y axes; unit plugs directly into MODEL 2 AUTOGRAF.

Bulletins describing these instruments are available and we'll be glad to send them to you. Write . . .

F. L. MOSELEY CO., 409 North Fair Oaks Avenue, Pasadena 3, California

FEEDBACK

sufficiently. A basic understanding of them is not difficult and their design is correspondingly uncomplicated, except for the problem of stabilization.

The widespread commercial use of compressed air suggests that the designer of servos for industrial use should give them (pneumatic servos) serious consideration.

Harold Levenstein
The W. L. Maxson Corp.
New York, N. Y.

Author Levenstein is so firmly convinced of the further need of studying pneumatic servomechanisms from a combined industrial and academic perspective that his employer has put him on "sabbatical" leave at the Instrumentation Lab, Dept. of Aero Engineering, MIT.–Ed.

Needed: more primers

TO THE EDITOR—

I would like to make a suggestion. Why don't you start a new section that would deal with "Control Engineering—Fundamentals,"—or "Refresher,"—or "For Beginners." Most of us are not very well acquainted with, or have forgotten, the fundamentals of control and instrumentation. All of us are not experts on control engineering, but there must be someone who really is and can make the engineering easier and more understandable for everybody.

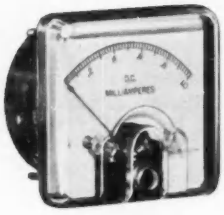
Articles like "Basic Math with AC Analogs" and "How to Analyze Control Systems Graphically," March 1955 issue, are excellent for the purpose. But I still think that CONTROL ENGINEERING may be improved by starting a new section.

Hope the above will work out well.

Thomas Garcia B.
Chief Chemist,
Laboratory T. U. G. N.,
Petroleos-Mexicanos,
Poza Rica Ver, Mexico

You asked for it. This issue starts two primer series, one on the basics of color measurement and one on the theory and practice of digital devices and systems. Several more primer series are scheduled, but at present we do not plan to set them off in special sections.–Ed.

ELECTRICAL INDICATING PANEL METERS AND PYROMETERS



Model 261 shown, Price $11.50

White-face, Black-face, or Colored Dials. Can be calibrated in any units: (Amps, KV, FPM, Angstrom Units)

Bulletin G-9

Large dial area—clearly visible. Less waste panel space. Easily lighted transparent plastic front and case. Anti-static treated. Tubing pointer normally supplied. Knife-edge and other types available. D'Arsonval movement in Alnico permanent magnet. Snap-fit construction, virtually dust-tight case. AC meters are rectifier type. Model 451 is 4½"; Model 351 is 3¾"; Model 261 is 2½". Meters with Zero Right, Zero Center or up to two-thirds of range suppressed can be supplied. AC and DC in multiple ranges. Meter ranges: DC or AC 0/20 Microamps to 0/50 Amps. 0/5 Millivolts to 0/500 Volts. (Minimum AC Range 0/250 Millivolts). Panel meters and pyrometers with black Bakelite cases also available. Model 301 shown. Write for Bulletin G-9

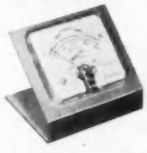
Pyrometers — Accuracy: 2%

Prices: $18.40 to $41.65

Medium resistance pyrometers (4 ohms per millivolt). Automatic, bimetal cold junction correction. Compensated for copper error. Furnished with adjusting resistor to take thermocouples up to external resistance of 10 ohms. Higher external resistance can be accommodated for some ranges. White face or black face dials. (Ranges: −400 to +3000°F.)

Ruggedized-Sealed

Both Panel Meters and Pyrometers can be furnished with shock-mounted movements in sealed cases. 2½", 3½" and 4½" diameters.



Stand-mounted Pyrometer Model C

for bench-type heat observations.

Prices $23.00 to $46.30.

Portable Pyrometer

Model B

Prices: $28.20 to $51.45.

Oak case-mounted pyrometer with 5' lead. Permits spot checks without requiring a permanent installation.

Lower-priced Kiln Pyrometers also available.

Bulletin G-9

CONTROLS

Versatrol Indicating Controller

For any variable that can be measured electrically. Adjustable control points. Automatic operation.

Catalog No. 3561 Versatrol (High Limit Automatic) with Single Contact 451-C Meter-Relay (0-20 Microamperes DC) Approx. 10 x 6 x 7 inches. **Price $154.25.**

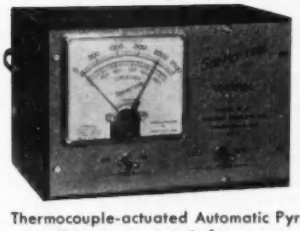
Bulletin G-7

The meter-relay "heart" of a Versatrol detects and indicates minute changes of current or voltage. It trips self-contained control relays (5 Ampere) as a result of these changes. The trip point or points are adjustable. This control action can be initiated by changes in linear or rotary speed, radiation, moisture content, heat, flow, level, electrical resistance—or variations in pressure, quantity, stress or strain, load, deflection, thickness, weight, color, or light, etc.

Some of the presen: applications are: Monitoring milling cutters (a dull tool pulls more load); automatic pH alarm; photocell light detectors; battery charger control; control of vacuum in TV tube manufacturing; conveyor belt speed control; moisture content control or warning.

Ranges of Versatrol Meter-Relays: 0/20 Ua to 0/50 A, 0/5 Mv to 0/500 V. Dials can be calibrated in any units—rpm, foot candles, feet-per-minute, counts per minute, deflection, deviation, etc. Signal input may be either AC or DC. Control sensitivity may range from 0.2 microamps to 1000 amps, or 0.1 mv. to over 500 volts. Shunts, series resistors and current transformers can be used in input to extend sensitivity range. Control can be high limit (on an increase in signal), low limit (on a decrease in signal) or double (control action on rise or fall of signal). Versatrol can be used for continuous on-off control (automatic) or for shut-down or alarm (requiring manual reset). No vacuum tubes are used.

Simplytrol Controlling Pyrometers



Bulletin G-8

Cat. No. 4531 0/2500°F.

Price: $132.00

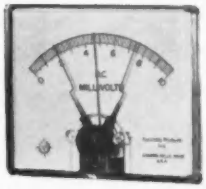
Thermocouple-actuated Automatic Pyrometer for controlling temperature in furnaces, ovens, kilns or other processes. Few moving parts—no vacuum tubes. Regular load relay is SPDT 5 Amps. Optional heavy duty relays to 40 Amps. Ten temperature ranges cover from −75° to 3000° F. Several special ranges to −400° F. "On & Off" control for gas, oil or electric heat. Indicating meter-relay is medium high resistance and has bimetal cold junction compensation. For use with all standard thermocouples. Indicating accuracy 2%. Control Accuracy depends on several factors but can be better than ½%. "Auto-Limit" switch changes unit from automatic controller to limit pyrometer for safety shutdown or warning.

BEARING TEMPERATURE MONITOR, using contact meter-relays operating directly from thermocouples to give immediate warning or shutdown upon dangerous temperature rise. Plastic case or ruggedized-sealed metal case meter-relays. Price about **$100** per monitor point.

METER-RELAYS

For Sensitive and Accurate Control or Alarm.

Meter-relays provide control of chemical processes or mechanical operations through alarm and automatic shut-off or continuous on-off control. Applications include: Bearing temperature alarm and shut-off on pumps, turbines, generators. Automatic speed controls for machines and conveyors. Computer shut-off if power supply voltage varies. Warning and control in radiation measuring equipment and processes. Automatic switching of standby equipment in microwave communications. Continuous control of pH. Use in radar warning systems.



Bulletin G-6

RANGES: D.C. or A.C. 0/20 Microamps to 0/50 Amps. 0/5 Millivolts to 0/500 Volts (Minimum A.C. Range 0/250 Millivolts)

Model 451-C Range 0/10 D.C. Millivolts. Price $61.00

Trip point adjustable to any point of scale arc. Sensitive to changes as little as 1%. One contact carried on moving pointer. The other on an adjustable pointer. When two pointers meet, contacts close and lock. Holding coil is wound directly over moving coil, locking action is electro-magnetic. Reset can be manual or automatic. Spring action in contacts kicks them apart forcefully. Three sizes of clear plastic models, 2½, 3¾ and 4½ inches (all rectangular). Contact arrangements: High Limit Single, Low Limit Single or Double (both high and low). Contact rating is 5 to 25 milliamperes D.C. Prices from **$30** to **$90.**

Ruggedized Meter-Relays

Metal Cases. Shock-Mounted; Sealed; Models 255-C (2½"), 355-C (3½"), 455-C (4½")

Narrow bezel permits longer scale length.

Same general specifications as plastic case meter-relays described above. Designed for use where unusual shock, vibration, humidity or temperature exists. $10 more than equivalent plastic case meter-relay.

Model 255-C Shown

VHS* Relay

(*Very High Sensitivity)

Model 266

Sample specs. are: 0.2 microamperes, (12,000 ohms coil) or, 0.1 millivolts, (5 ohms.)

The VHS is a D'Arsonval moving coil relay, internally shock-mounted. The screw-on cover is gasket sealed. Connections: 9 pin octal style. Dimensions: 1¾ diameter x 2¼ long. Weight: 4 ounces. Sensitivity: Infinite variations from 0.2 Ua. to 10 Amp. or 0.1 Mv. to 500 volts, self contained. Higher volts or amps with external multipliers or shunts. A.C. rectifier types. Trip point accuracies to 1%. Differential 1%. The degree of resistance to shock and vibration depends upon sensitivity and type of action wanted. In general, the relays will not be permanently damaged by shocks of 100G's and vibrations up to 2,000 cps at 3 to 4 G's. The most sensitive relays may close their contacts under these conditions.

Contacts: SPST or SPDT, 5-25 Ma. D.C. Other ratings to ½ Amp. A.C. A locking coil gives high pressure and chatter-free contact even under shock and vibration. Prices **$20** to **$80.** Delivery 4 to 6 weeks.

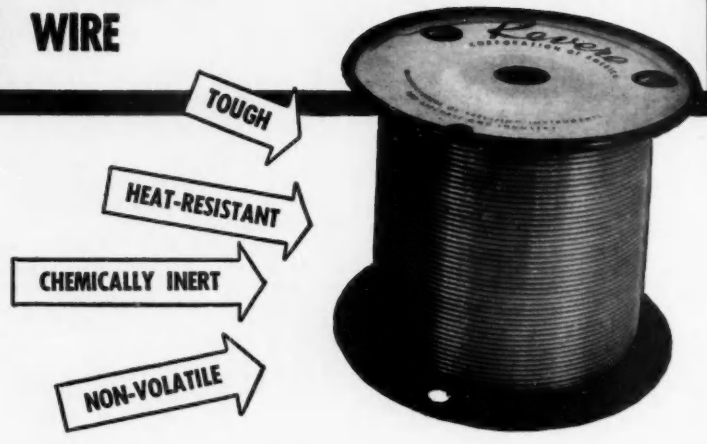
Bulletin G-6

MANUFACTURER: ASSEMBLY PRODUCTS, INC., CHESTERLAND 22, OHIO. Phone: (Cleveland, O.) HAmilton 3-4436, or P. O. Box 298, Desert Hot Springs, Calif. Delivery is three to six weeks on most special orders. Certain ranges of Simplytrols, indicating pyrometers, and contact meter-relays are kept in stock for immediate delivery. We have over-runs of other ranges also in stock if they will meet your experimental needs. We sell direct.

REVERE

Revcothene*

INSULATED WIRE



Because of its extreme toughness, high heat resistance, and chemical inertness, Revcothene insulated wire is widely recommended for hermetically sealed equipment . . . for devices operating with small gauge wire at high temperatures . . . and for conditions where corrosion is a problem.

Revcothene is silver-plated copper wire with an extruded coating of monochlorotrifluoroethylene. Even at 150° C. (302° F.) the insulation is inert . . . with no volatile lacquers or plasticizers to ruin contacts. Revcothene withstands abrasion and flexing, and resists such corrosives as ozone, acids, alkalis and petroleum products.

Available in eight standard sizes from 28 to 10 gauge . . . in 15 colors. Flexible strandings, copper or silver braid shielding, heavy wall insulation and jacketing can also be furnished. Multiple-conductor cables are also available.

Revcothene is only one of many insulated wire and thermocouple wire products made to exacting specifications by Revere Corporation of America. Technical design assistance gladly offered. Write today.

TYPICAL SPECIFICATIONS — 22-Gauge Revcothene Wire

Spark Test Voltage	7500
Insulation Resistance	1000 megohms/1000'
Operating Temperatures:	
Flexing Application	—40° C. to 135° C.
Non-Flexing Application	—65° C. to 150° C.
Flammability	Does not support combustion
Operating Voltage	1000 volts
Water Absorption	0.00
Effect of Acids & Alkalis	Generally unaffected
Cold Flow (Compressive Strength)	32,000 PSI
Abrasion Resistance (MIL-T-5438)	Passes 36"-400 grit aluminum oxide with 0.3 pound weight

*Revere's tradename for monochlorotrifluoroethylene

Revere CORPORATION OF AMERICA 2

WALLINGFORD, CONNECTICUT A subsidiary of Neptune Meter Company

FEEDBACK

Norway reports

To the Editor—

As Norway did not take part in wartime servo work, a major postwar effort has been made to bring the country up to date in this important technical field.

Administration and Co-ordination of Research

Since the war industrial and scientific research in Norway has been coordinated by the Royal Norwegian Council for Scientific and Industrial Research. Research activities have been concentrated in the three cities of Oslo, Bergen, and Trondheim. The Council has an ambitious program to increase both basic and applied research activities.

The most important result in the industrial sector is the erection of the Central Institute for Industrial Research, which is now in operation in Oslo. This institute will mainly do sponsored research for industry, as most of our industrial companies are too small to carry on their own research.

The Norwegian Institute of Technology in Trondheim has after the war established a separate division for industrial research, and the Chr. Michelsen Institute in Bergen, which has been in operation for 25 years, has recently expanded its industrial research sector. All three institutions have groups working on servo and instrumentation problems.

The Royal Norwegian Council for Scientific and Industrial Research has awarded scholarships to research personnel, enabling them to work in development centers abroad, especially in the U. S. A. and in Great Britain. American scholarships, such as the Fulbright Foundation's traveling grants, have also given substantial assistance. As a result there are now in Norway a number of engineers with several years of servo training. The Institute of Technology has recently started courses covering servo and process control. In the years to come an increased number of servo engineers will be available to industry in this country.

Perhaps the most striking example of the Research Council's success with its basic program is the construction of a heavy-water-moderated uranium reactor which went into use in the summer of 1951. The reactor demonstrated that we were able to build

different types of automatic controls for a fairly complex process.

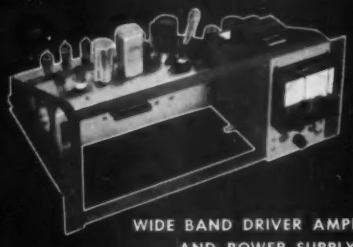
The Position of Industry

Most Norwegian industry has not yet realized the possibilities of instrumentation and control. We must in this connection remember that the main source of information about industrial control in the western world is the experience gained in the industries of the United States. It is not at all obvious to the management of small companies in our country that it is economically justified to carry automation as far as American industry does. We cannot expect management to accept outright the servo point of view, i.e., that we have just started on a line of development which may lead us through an industrial revolution to a completely new production technique in most industries. An attempt to introduce more instruments and control equipment in factory, workshop, and office will meet with many difficulties. In addition to the problems that are also well known in the States (i.e. servo theory is difficult, plant re-design may be necessary to make full use of automatic control, automatic control is developing so fast that it may pay to sit back and wait), I will mention some obstacles which at the present time are equally important here.

In the U. S. the instrument manufacturers seem to do an excellent job in their training schools to educate instrument technicians and service men. With us the situation is quite different. With few exceptions instruments are sold here through representatives who have limited means of giving the customer technical service. In theory the technical skill and resources of the manufacturer are at our disposal, but experience has shown that difficult technical matters are best treated through personal discussions between customer and instrument supplier. Only large projects can bear the expenses of a specialist's crossing the Atlantic. The ratio [labor wage: instrument price] is an important factor for the evaluation of how far automatization should be carried. Modern instruments are mostly made by American firms and their foreign subsidiary companies, and we have got to pay American price + transportation + customs duty. Our wages are much lower than the U. S. average, and our industry will therefore make more use of manual labor than would

SANBORN
OSCILLOGRAPHIC RECORDING EQUIPMENT
answers a broad range of recording problems

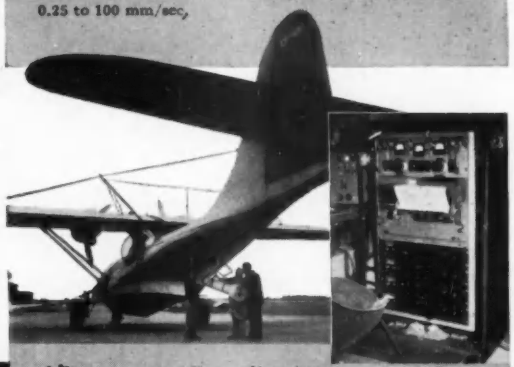
● SEPARATE COMPONENTS



WIDE BAND DRIVER AMPLIFIER AND POWER SUPPLY

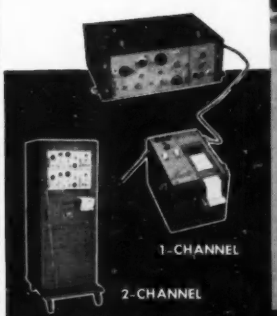
THIS amplifier (Model 150-300/700) is designed for use with low power galvanometer elements (output ±25 ma full scale into 100 ohm load), an oscilloscope and/or a panel meter, individually or simultaneously. Eleven plug-in type, interchangeable Preamplifiers are available for use with it, and include: AC-DC, Carrier, DC Coupling, Servo-Monitor, Log-Audio, Low Level, Input Network, AC Wattmeter, Frequency Deviation, Stabilized DC, and an RMS Volt/Ammeter.

Other available separate components include Recorder Assemblies from 1- to 8-channels, with chart speeds from 0.25 to 100 mm/sec.



A "component" application

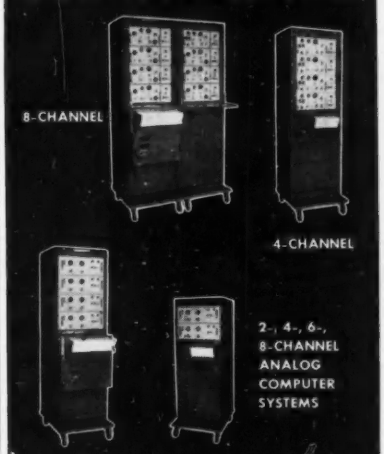
FOUR Model 67-300 DC Amplifiers and a Model 154-100 four-channel Recorder Assembly are integrated with other equipment aboard a "flying geophysical laboratory" by PSC Applied Research, Ltd. of Toronto to record data from dual frequency detector magnetic survey equipment and a radiation detector, plus elevation variations during flight. The simultaneous recording of all four provides valuable reference data when interpretations are being made.



1-CHANNEL

2-CHANNEL

● COMPLETE SYSTEMS



8-CHANNEL

4-CHANNEL

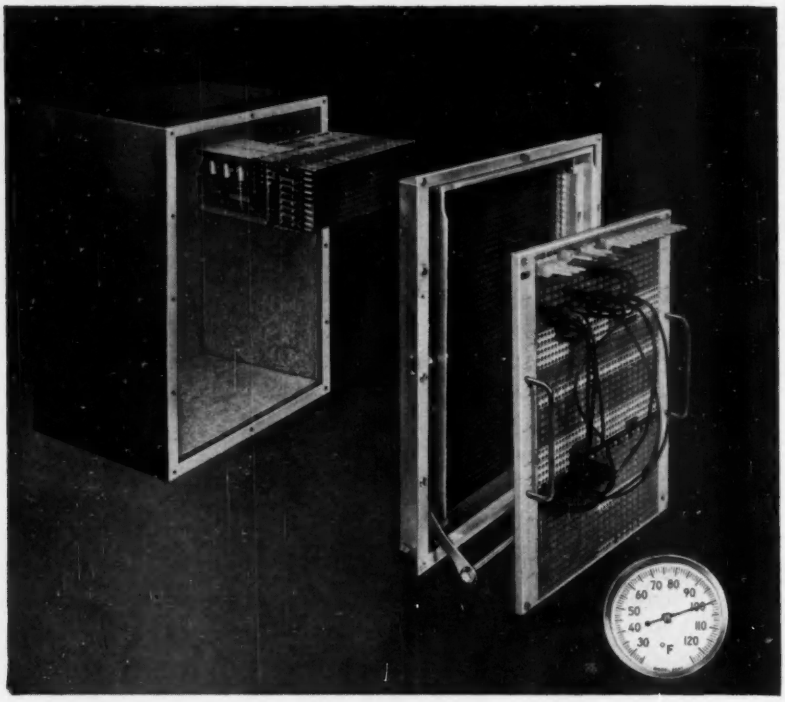
2-, 4-, 6-, 8-CHANNEL ANALOG COMPUTER SYSTEMS

A Sanborn "150" system starts with a choice of an 8-, 6-, 4-, 2- or 1-channel basic assembly, to which the user adds any combination of plug-in type Preamplifiers to meet the numerous and changing recording requirements. Special 8-, 6-, 4-, and 2-channel systems are available for recording the output of analog computers, or other applications involving 1 volt/cm sensitivity. Added to this application versatility and operating flexibility of Sanborn systems are other advantages, such as inkless recording in true rectangular coordinates . . . high torque (200,000 dyne cm) galvanometer . . . time and code marking . . . numerous chart speeds.

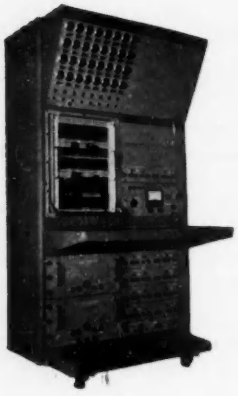
Let Sanborn engineers help you solve your recording problems. Write for complete specifications and performance data on any Sanborn component or system.

SANBORN COMPANY
INDUSTRIAL DIVISION
CAMBRIDGE 39, MASSACHUSETTS

News in Analog Computing...



ASSURES MAINTENANCE OF YOUR EQUIPMENT'S ORIGINAL ACCURACY...



It is of understandable importance to you, when investing in analog computing equipment that you have definite assurance the equipment will maintain its original accuracy in use.

Such assurance is yours, in Electronic Associates' Computer Group Type 16-31R. All critical elements, such as precision computing networks, passive elements and relays are contained in a blower-equipped, thermostatically controlled oven located directly behind the patch bay — with temperature controlled to 100° F plus or minus one degree — assuring maintenance of accuracy and stability.

This 16-31R is the Computer which can be expanded by a unique building block system to the most complex systems. Demonstration and rental of computing time is available at EAI Computation Center, Princeton, New Jersey. Details on request. Write Dept. CE-12, Electronic Associates Inc., Long Branch, New Jersey.

Visit our booth at the Instruments Society of America Conference.

ELECTRONIC ASSOCIATES — EAI SETS THE PACE (PRECISION ANALOG COMPUTING EQUIPMENT)

LONG BRANCH, NEW JERSEY

FEEDBACK

be the case in the States.

Norwegian industry always bought much technical equipment from Continental Europe, especially Germany. The Germans did not develop servo techniques very far during the last war, and German instrument manufacturers have as a whole been lagging behind their U. S. and British competitors. During the last few years, however, we have seen an increasing number of German instruments very well suited to fill the needs of modern industry. As the instrument market is expanding, the small countries will doubtless also take up production of industrial instruments. Sweden, Denmark, and the Netherlands are examples of countries that have already some instrument factories. Instruments are, however, still sold on a seller's market. It is likely that as competition increases, prices will come down. Some industrial companies are, with this possibility in mind, showing an increasing interest in the use of modern instrumentation technique.

Many applications of automatic control are subject to military security regulations. But even in the open sector the publication of much important work is subject to a long time delay. Since my stay in the U.S.A. I have been hoping that it should be possible to get a system established which will bring about a much more efficient exchange of important technical and scientific information in the servo field. The advent of CONTROL ENGINEERING is here a good step forward. The cost of U. S. technical journals in Europe is, however, so high that very few private persons can afford to subscribe. Consequently these papers do not get the wide circulation they ought to have, and they are mainly read by specialists who first of all want to obtain exhaustive information about advanced theoretical and experimental work. For control engineers it is also necessary to get regular technical information about new instruments and equipment. Many of us have felt the need for dynamic response data for instruments, and I hope that the manufacturers very soon will be able to supply such data with all control equipment. This would enable system designers to select the best instrument for a specific application, and thus make better control systems available for science and industry.

Haakon Sandvold
Chr. Michelsens Institute
Bergen, Norway

another conquest..... this time in electronics

YOU TOO will be right ON TOP with the new Solartron Transfer Function Analyser. Hailed at the International Instrument Exposition, Los Angeles, as the world's foremost servo test equipment, its advantages over other contemporary types will lead you to use it, as do all United Kingdom G.M. manufacturers. Cable Solartron for our engineer to give you a demonstration, or write for fullest information.

- **Tests AC, DC or carrier servos**
- **Plots high accuracy Nyquist diagrams**
- **Covers 0·1 c/s to 1,000 c/s**
- **Independent of harmonics, noise and spurious frequencies**
- **Answers G.M., fire-control, simulator, computor, vibration, magamp and all servo problems**

THE SOLARTRON ELECTRONIC GROUP LTD.

Thames Ditton, Surrey, England

Cables: Solartron, Thames Ditton **Telephone: EMBerbrook 5522**

MODEL MA640 MODEL MA2850 MODEL MA65

RUGGED • ACCURATE • TUBELESS

MAGNETIC AMPLIFIER DC SOURCES

(MA-NOBATRONS*)

Sorensen MA-NOBATRONS* have been designed for industrial applications and unattended installations where the utmost in maintenance-free service is required.

SPECIFICATIONS

	MODEL MA65	MODEL MA640	MODEL MA2850
INPUT	105-125VAC, 1Ø, 60 cycles		190-230VAC, 3Ø, 60 cycles 4-wire wye.
OUTPUT	6VDC, adj. ±10%	4.5-7.7VDC, adj.	23-32VDC, adj.
LOAD RANGE	0-5 amperes	0-40 amperes	0-50 amperes
REGULATION	±1.0% for any combination of line and load conditions		
RECOVERY TIME	0.15 seconds under worst conditions	0.2 seconds under worst conditions	0.5 seconds under worst conditions

Contact your local Sorensen representative, or write for further information. If you have special requirements in magnetic amplifier DC sources, write or call the Applications Engineering Department, and your problem will receive prompt attention.

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*Reg. U.S. Pat. Off.

CONTROLLED POWER FOR RESEARCH AND INDUSTRY

SORENSEN

A CONTROL PERSONALITY

LEE AVERA spurs interest into action

F. L. (Lee) Avera insists he is not a control engineer, but "just a chemical engineer who is interested in control". But there are two kinds of control engineers. There is the man specifically trained in the art and concerned solely with its use. And then there is the engineer who "discovers" control—and who often uses it more adroitly and with more telling results than the keenest specialist. Lee Avera is a brilliant example of the latter.

Today Lee is director of chemical activities for all Skippy Peanut Butter factories. The unique, high-quality continuous process that Avera developed for his company is kept under wraps. Otherwise we could print vivid proof here of Avera the "control engineer" at work today. But we only have to look closely at the man to imagine what has been done to optimize the manufacture of "Skippy".

A One-Man Task-Force

Avera the control engineer starts to emerge when you consider his war stint in the Navy. When the Navy realized what it had in Lee Avera, it rushed him off a destroyer-escort in the Pacific and put him on a lonely island off Norfolk, Va. His assignment: to find a way to salvage contaminated fuel oil. If you read the Norfolk papers during August, 1945, you would know this one-man research project saved 5 million gal of oil in the Atlantic war. And that it won for Ordinance Specialist Avera a Navy Commendation Citation from Secretary Forrestal.

Lee Avera was solving fundamental problems long before the war. As a young engineer he was excited by the remarkable changes then taking place in pure physics. His interests ranged from a system of electro-negativity values which caught the attention of Linus Pauling, to a formula he developed related to mass-proton ratio, which predicts the end-point of natural radio-active disintegration. He took a position on aspects of gravity that brought him a warm letter from Albert Einstein. And his attention to electron inertial concepts prompted a series of letters from Dr. Willis Rodney Whitney, founder of the General Electric Laboratories.

When Does "Interest" Become Occupation?

It is obvious that when Lee Avera is "interested" in a subject it gets more than cursory attention. So it goes for measurement and control. At present

Lee Avera focuses on unshackling benchbound control.

Lee is concentrating on high-speed quality measurements that can apply to production control loops. Among his developments are techniques for measuring moisture and fat in product. Also, a number are trade secrets. A clue to the latter is seen in his prediction that "the future holds further shift from macro to micro components, and eventually micro control complexes." Another clue: he recently developed an atlas of electronic valence energies for evaluating chemical structures.

At home Lee Avera complements his professional activities with some non-scientific "interests" of equally wide range. He plays the trumpet, several woodwinds, and the piano, and has both composed and arranged orchestral music. He is active in the local Rotary Club, collects and experiments with various art forms, and is deep into the literature of psychology and philosophy (another famous correspondent of his is C. G. Jung of Zurich, who complimented Avera on an idea concerning Jungian archetypes). And to further confirm the fact that he is indeed a "control engineer", Lee Avera is attempting to learn Sanskrit (which some readers claim we use in CONTROL ENGINEERING).

ALLIED'S NEW

Sensitive
Versatile
Stable

This new polarized relay, designed and manufactured by Siemens & Halske Company of Germany, is now available from Allied Control, and in the near future will be produced by Allied with the technical assistance of Siemens & Halske.

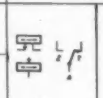
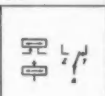
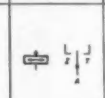
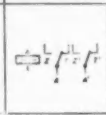
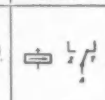
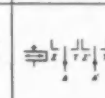
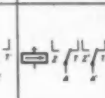
Types Trls 63 to 69 are recommended for use in industrial applications where the special features of a polarized relay are required, or where its inherent high sensitivity, long life and precision operation are desired. They are available with transparent or metal dust covers and are produced with solder terminals or 16 point plug-in bases (sockets are available from Allied Control). Bulletin TR gives complete details.

For military applications, these relays will be available hermetically sealed with either solder terminals or 16 point plug-in base.

7

POLARIZED RELAY

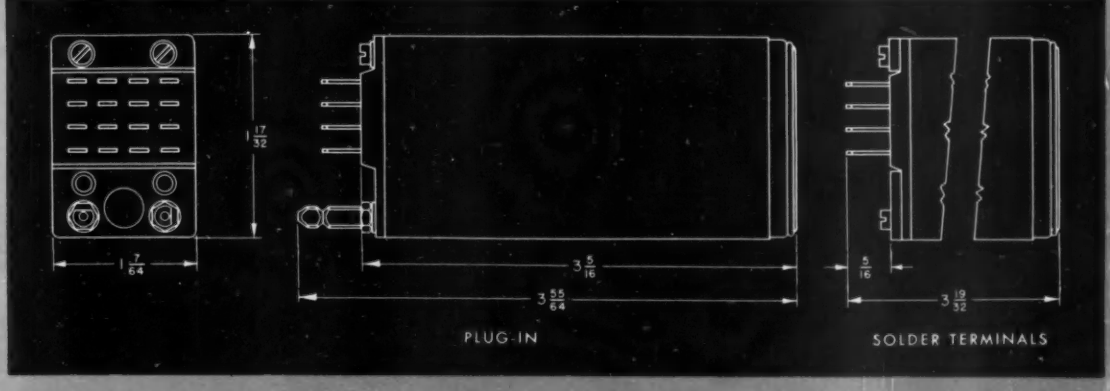
Specifications For Allied's Types Trls 63-69

Type Number		Trls 63	Trls 64	Trls 65	Trls 66	Trls 67	Trls 68	Trls 69
Description	Positions	2		3	2	2	3	2
	Operation	Magnetic Latch						
		High Contact Pressure	High Sensitivity	Null-Center	Magnetic Latch	Spring Biased	Null-Center	Spring Biased
Contact Arrangement		SPDT		SPDT	DPDT	SPDT	DPDT	DPDT
Circuit Symbols	for telegraphy							
	other purposes							
"Operate" Excitation	Amp. Turns	7	2	2.2	5.5	5	4	15
"Operate" Power	μ Watts	500	40	50	300	250	160	2250
Working Excitation	Amp. Turns	15	4	6	10	10	10	25
Working Power	μ Watts	2250	160	360	1000	1000	1000	6250
"Release" Excitation	Amp. Turns			2.2		2.4	4	5
Max. Rate of Operation	Oper./Sec.	200	200	200	200	100	200	100

Contacts:	Silver, General Purpose
	2 amp., 28v d-c resistive load
	Platinum Alloy A. Low-Level
	Applications up to 1 amp.
	Platinum Alloy B. Heavy Duty
	Applications above 1 amp.
	Max. Continuous Current 5 amps.

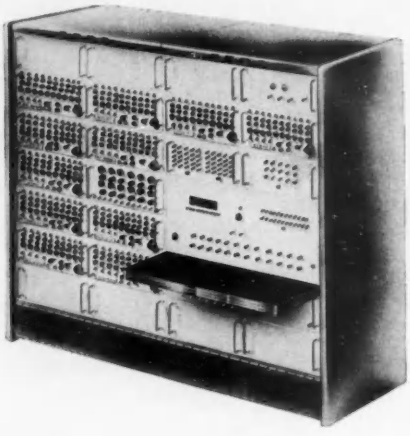
Dielectric Test Voltage	Coil to Frame	500v rms.
	Contact to Contact	350v rms.
	Contact to Frame	500v rms.
	Coil to Coil	150-500v rms.
Standard Coils	Resistances from 1.1 to 18,000 ohms	
	Max. number of windings	8
	Max. Continuous Loading	1 watt
Temperature	Max. Ambient	85°C

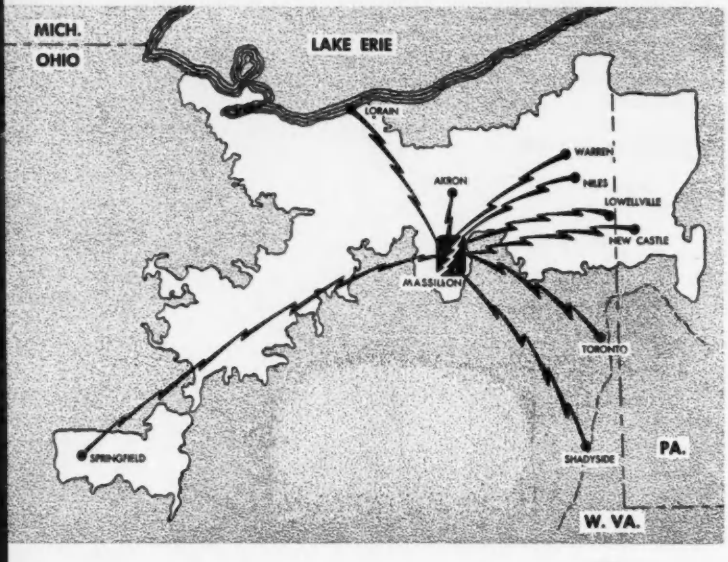
DIMENSIONS



ALLIED CONTROL

ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N. Y.





Sometime in 1956 a complete electrical power network—covering 9,000 sq miles, nine plants with 35 generating units, and a 100-million kw hr weekly output—will fall under the control of a single special-purpose analog computer in Massillon, Ohio.

Computer Will Control Major Power System

Computer technology—and automatic control—will climb to a new plateau next year when Goodyear Aircraft Corp. integrates its GEDA (Goodyear Electronic Differential Analyzer) into Ohio Edison's extensive power load-control system which cobwebs the northeast part of the Buckeye State.

Today the Ohio utility company regulates the output of the area's major generating units from a Leeds & Northrup load control console in its central operations office in Massillon, and telemetered information, meter readings, and pre-calculated charts guide the dispatchers in remote-manual loadings of distant generators. With the new analog computer linked into the L&N system, the human element will be completely removed from the loop. Gains in loading speed and efficiency alone are expected to pay for the added equipment within two years.

Since its post-war emergence there has been a feverish rush to tie automatic computing—both digital and analog—into power network systems. Ohio Edison's project will be the first big commercial venture into computer controlled power and the first to rely on an electronic differential analyzer to do the job. Both Edison and Goodyear engineers are sure that this computer's unique ability to simulate station and system changes makes it a practical standout for power control.

As the artist's sketch above shows, the computer will be a compact console made up of several sliding-drawer modules—one for each power plant in the system. Forming the module will be a group of plug-in printed-circuit resistor-diode network function generators, each simulating a generating unit in the module's plant. The knobs and switches on each station simulator will add such pertinent information as local power limits and fuel and maintenance costs for a particular unit. Altogether, the computer will be able to handle coordination equations for eleven stations, eight tie lines, and four non-conforming loads.

In operation it is planned that the

Readying up GEDA components in Goodyear's Akron plant. The Massillon unit will contain 50 plug-in dc amplifiers

computer will reckon the composite heat rate of all the generating plants and multiply this by fuel cost. The calculated incremental dollars per megawatt hour will then be used in solving coordinating equations to economically balance and load all generators throughout the network. This will include matching newer high-pressure steam cycle equipment with older low-pressure units in the system.

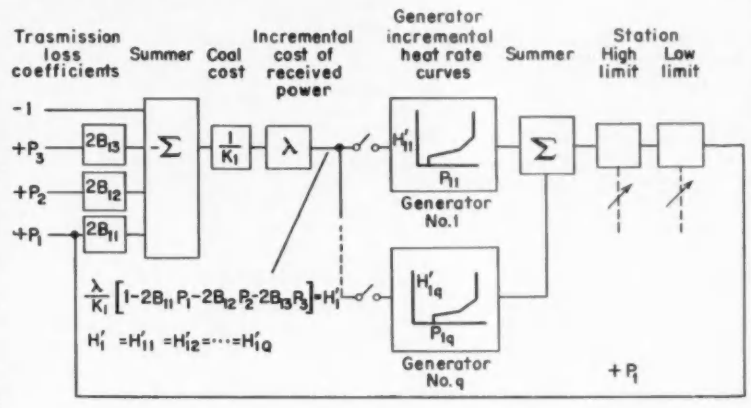
Besides individual generator limit dials, each station simulator will have overall high and low limit adjustments. Hence during storms and other emergencies the computer will offer realistic control of station loading limitations.

The special-purpose GEDA will tie neatly into the existing central control system. A second motor-driven pen in each L&N station recorder will be positioned by computer output. This "required" computed generation for each station will continuously reset the control points on the present console. Corrected signals thus will pulse over carrier telephone circuits to throttle the remote generators to a pattern of highest efficiency.

Automatic control of system balance will only be part of the planned job for the computer. A tie-line cost-computing circuit will determine purchased power at various points in the network. This information, plotted on a standard X-Y recorder, should prove vital in preparing station budgets. It will also be possible to feed past performance data into the computer for forecasting studies.

Ohio Edison's decision to pioneer completely automatic power control took shape three years ago when Goodyear's Dr. H. R. Hegbar and C. D. Morrill broached the subject to the local (Akron) section of AIEE. In the audience were Edison engineers R. H. Travers and D. F. Shook, who were to enthusiastically team with the speakers in researching and developing the idea. The engineering profession got a full view of the scope of the project last winter, when Morrill and J. A. Blake presented their paper, "A Computer for Economic Scheduling and Control of Power Systems", to the national meeting of AIEE.

HOW THE COORDINATION EQUATIONS WILL BE SOLVED:



The block diagram above represents a station simulator and shows how its incremental heat rate, H_i' is coordinated with similar information from other function generators—inputs P_1, P_2, P_3. The resultant sum is divided by K_i, represented by a potentiometer, and multiplied by λ through a potentiometer with a shaft common to its counterpart in each of the station simulators. The resulting voltage, H_i, is applied to a set of electronic function generators which relate unit power to incremental heat rate. Thus, depending on generators connected and functions stored, the resulting voltage represents station power for a particular value of λ.

• • •

Still More in the COMPUTER ROUND-UP

Analogs Massed for Air Force

Wright Air Development Center in Dayton, Ohio, will soon be enhanced with what is reputed to be the largest flight simulation center in the world: a million-dollar analog computer facility now being assembled by Reeves Instrument Corp. of New York. The project will occupy 6,000 sq ft and will hold a four-section integrated computer. Each section will operate independently, or in various combinations with the other three.

When asked for details, Reeves admitted that the new facility will basically resemble its well-known "Project Cyclone", which it operates for the Navy in New York (see CONTROL ENGINEERING, July, 1955). But, says Reeves, it will be "larger and more modern in every way". For example, automatic machine programming will be used for repetitive runs, and a patch-board verifier developed by W. M. Warshawsky and W. G. Braun at the Aeronautical Research Laboratory, WADC, will digitally verify each problem as it is "patched" and print a record of the exact circuit.

Wright Field's new giant analog will focus mainly on the development of guided missiles and other airborne armament.

Digital Deliberations Ahead

Engineers will converge on the subject of computers at two widely scattered points in the next few weeks. They will gather Oct. 13-15 in the Student Memorial Building at the University of Denver for a programming practice workshop featuring Denver Research Institute's digital and analog units, and will listen to several authorities present papers. Three weeks later (Nov. 7-9), AIEE, IRE, and the Association of Computing Machinery will sponsor in Boston the Eastern Joint Computer Conference, which will dwell mainly on the new ways that computers are being used in business and industry. Twelve papers will be aired at four sessions in the pleasant rooms of the Hotel Statler.

Synthesizing a Refinery

By this time Shell Development Co. may be hard at work on one of the most intriguing problems for a digital computer: setting up a mathematical model of a refinery. This is just one of the jobs that the company hoped to perform when it recently ordered its new Electrodata computer. Other possible chores include data reduction of teletype information from various Shell

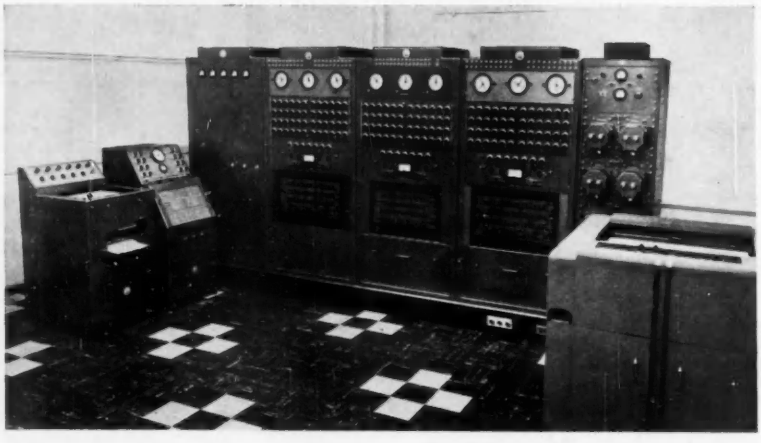
Oil and Shell Chemical plants, and the simulation of many of the experiments that are daily routine at the research laboratory. Shell estimates that the new $220,000 computer can calculate a mass spectroscopic analysis in about 20 sec—a job that used to tie up a scientist for several hours over a desk calculator and pad.

Hey, That's My Seat

Hard on the heels of the triumphant announcement by New Haven RR's Pat McGinnis that reservations will be automatic on his line (see *What's New*, June, page 16) comes this dual note: New York Central will soon guarantee its seats with "Centronic", and United Air Lines has put into effect its straightforwardly named Automatic Reservations System. The Central's set-up is a product of Teleregister Corp. This control manufacturer will maintain the high-speed magnetic memory drum for the system in its Stamford, Conn., laboratories. All railroad agents east of Buffalo will be equipped with a Keyset that will give immediate access to the memory. The memory will store an estimated 171,000 accommodations and will have a daily input-output of around 5,000 reservations each day, with peak loads of up to 3,000 calls per hour. UAL uses IBM units in its electro-mechanical reservation system. The ticket seller is equipped with a punch-button machine connected by wire to the central reservation control panel. The check is made swiftly on punch cards and the confirmation sped back for indication on the seller's machine.

SWAC Is Now A-Pealing

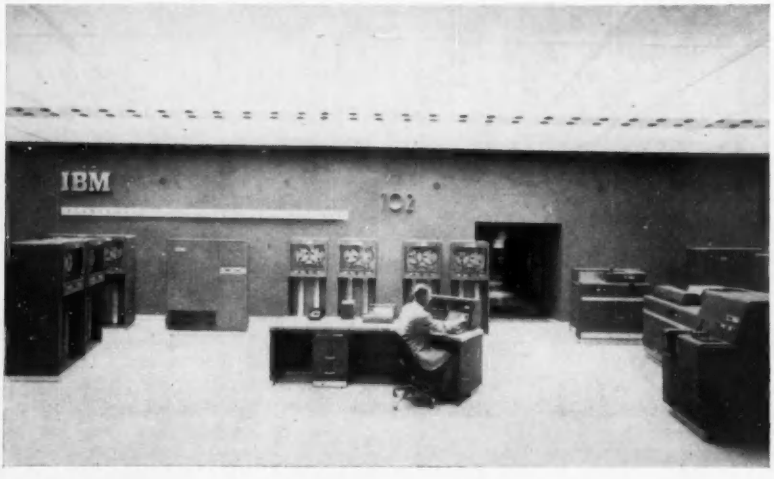
Mellifluous but strong-muscled undergraduates may soon stop dangling from bell ropes at UCLA if SWAC has its way. For SWAC, the campus computer, has solved the problem of programming complicated peals—which can, incidentally, involve 15,000 changes and take nine hours to ring. It took a fugitive from Cornell's bell tower to fit SWAC to its new task. Dr. Robert J. Walker, on leave from the mathematics department in Ithaca to do research at UCLA's Institute of Numerical Analysis, is the man who may get the poison-pen notes from carillonneurs (both North and South).

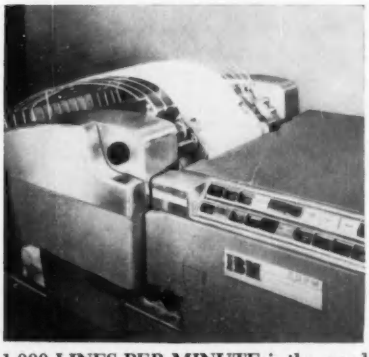


COMPUTING CENTERS FOR N. Y.

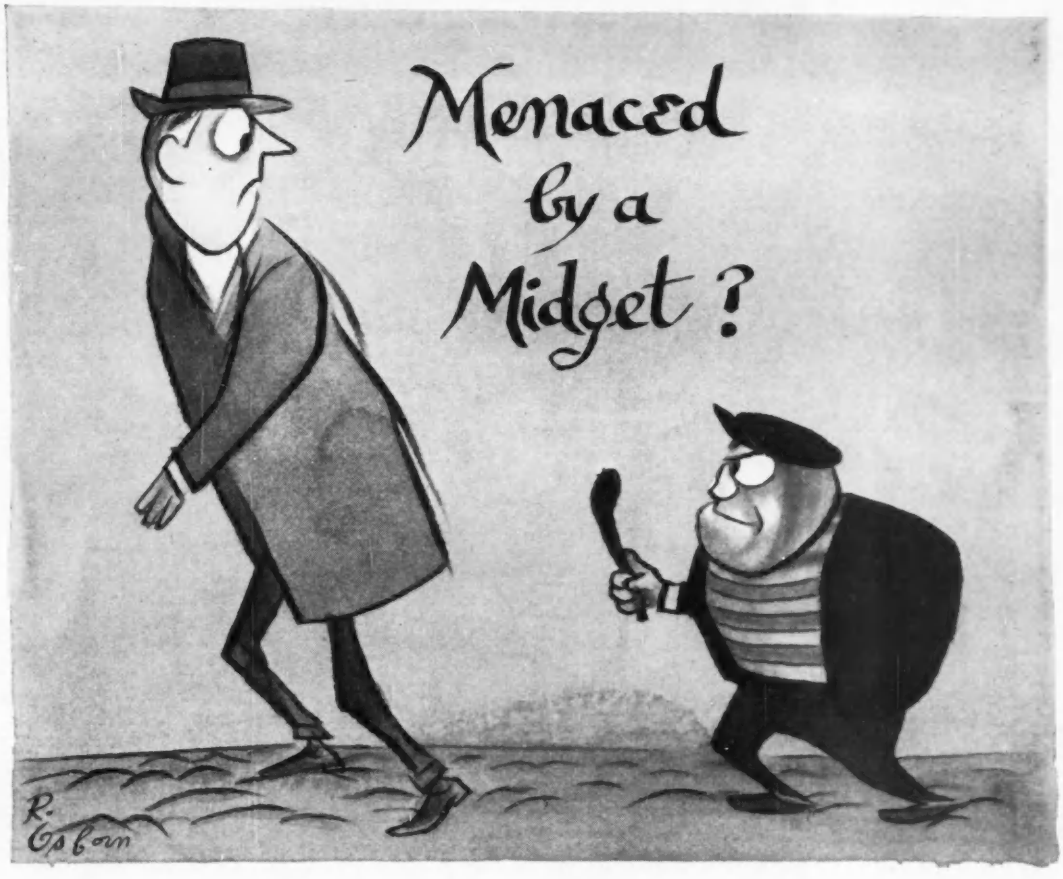
ANALOG computer facilities (left) have been established by Dian Laboratories at 611 Broadway, Manhattan. In charge of the staff is Dr. Stanley Fifer, formerly head of Project Cyclone. The services are available on a rental basis.

DIGITAL computing facilities (below, left) of IBM in its center at 59th Street and Madison Avenue have been enhanced with this splendid new room holding a complete 702 unit. Other computers at the center open to business and industry: the 701 and 650.



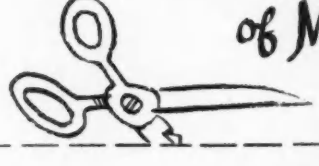


1,000 LINES PER MINUTE is the speed of this new printer in IBM's revamped Data Processing Center. It will print 120 characters per line, feed continuous forms 22 in. long, and prepare 7 legible copies.



Being hounded by a problem in miniaturization? Are you harassed by a toughie in the increasingly critical field of design diminution, weight and size reduction, power and component capsulation? If you are, simply stop in at the nearest scissors store. Get a pair of pinking shears and cut out this coupon. It will get you the complete catalog of MPB's ✳ such as these

BALL BEARINGS ACTUAL SIZE



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Geneva Shows Atomic Control: HOW IT SIMULATES & SCANS —and what happens without it

HOW TO SIMULATE control of a swimming pool reactor was a big attraction at Geneva. This Leeds & Northrup unit is offered for sale as a training "package."

HOW TO SCAN an explosive release of nuclear energy was the function of this Minneapolis-Honeywell exhibit in the official U. S. display.

As CONTROL ENGINEERING predicted (see August, 1955, page 13), nuclear control technology did indeed show signs of "zooming ahead" after the splendidly frank and fruitful Atoms for Peace conference at Geneva, Switzerland, this past summer.

Our correspondent at Geneva, Mr. Sam Scharff, a New York consulting engineer, had this to say:

"While only a few of the sessions emphasized control theory and practice, the subject of automatic control was never out of sight. Particularly in those papers on reactor technology and in the general run of hardware which was shown in both the commercial and official exhibits."

Sam's letters made these points:

▶"Far and away the prime attraction was Oak Ridge's swimming pool reactor. Hordes of people—including a man named Ike—got their fingers wet as control engineers by running the Leeds & Northrup simulator.

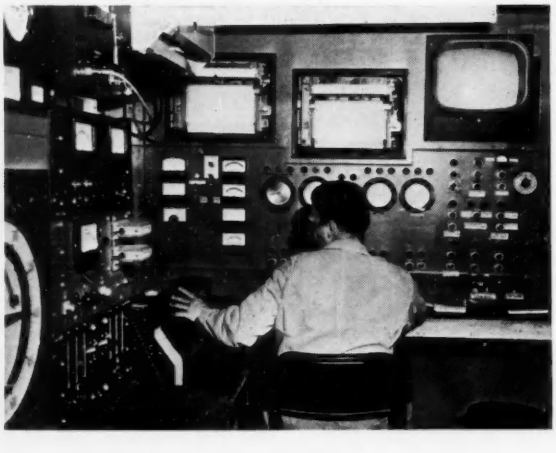
▶"The hardware displayed was remarkably specialized. Bendix and Honeywell competed with elegant units (simulators and computers) in England's Elliott Bros. and France's Laboratories Derveaux booths. I was impressed with the latter's 'Djinn', a $13,000 analog with many of the advanced features of top American units.

▶"Technical content of the papers was very high—particularly those offered by Zinn and his Argonne group on boiling water reactors. Quite a few of the papers intimated that homogeneous reactor control *without rods* would soon be the vogue."

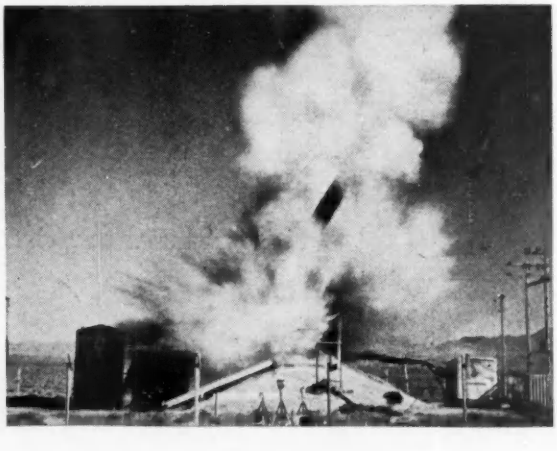
But control engineer Scharff also had this negative impression: "It amazed me that there was little sign of the dynamic analysis approach being taken in the design and operation of nuclear processes. It seems to me that nuclear scientists have a tremendous opportunity if they would integrate control into their thinking."

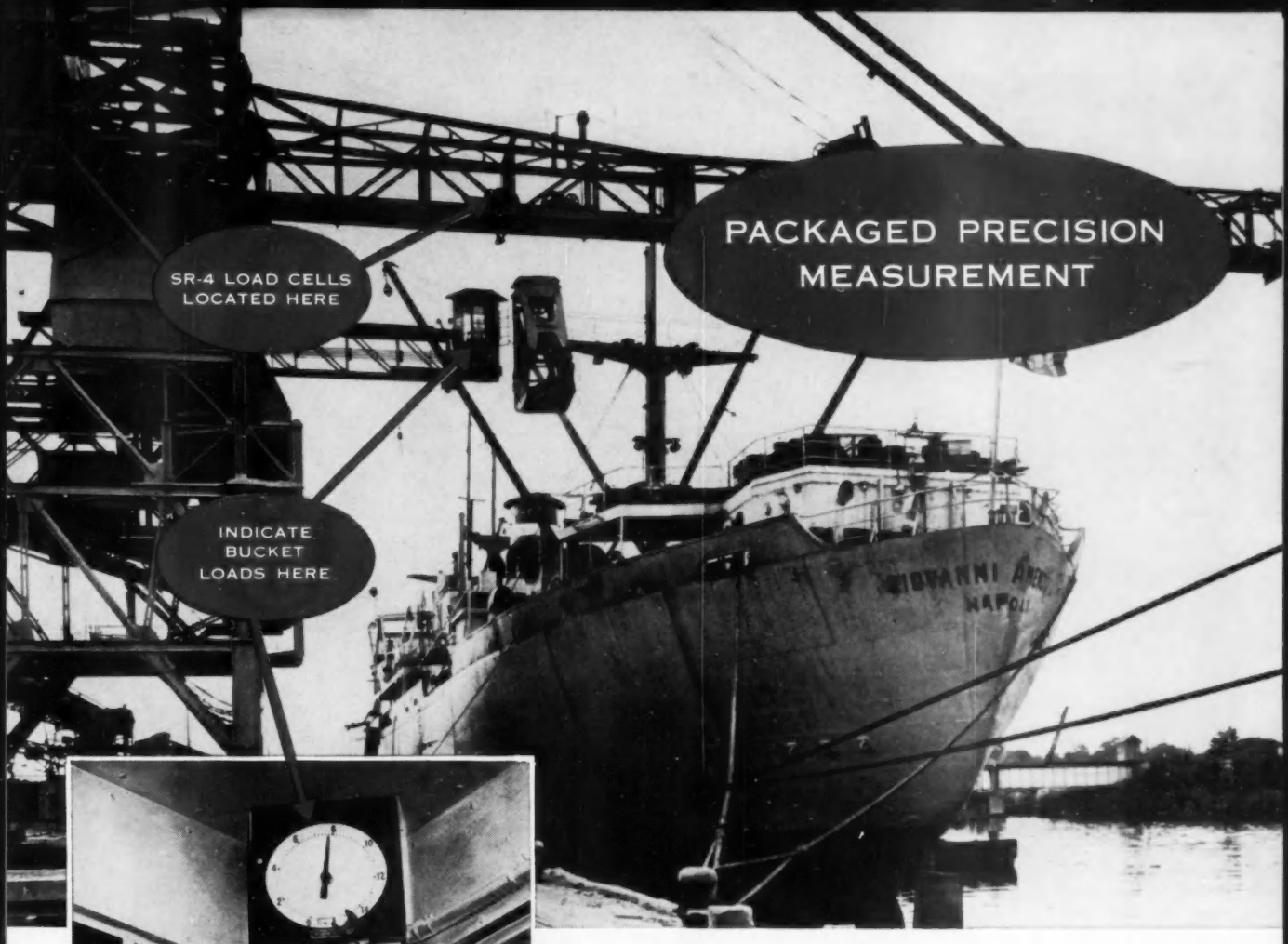
Armed with a copy of August CONTROL ENGINEERING, Sam Scharff also paid a visit to the official Soviet display in the handsome League of Nations building. There an affable engineer named A. S. Shtan, from Moscow's Academy of Sciences, showed Sam some "solid looking radiation thickness gage assemblies that the Academy had developed and 'sold' to several Russian factories. As of this date, the gage is still confined to open loop control. But an automatic system is in the works." Incidentally, Engineer Shtan avidly latched onto Sam's copy of CONTROL ENGINEERING.

HOW TO CONTROL the conversion of atomic energy into electrical power appeared in this film screen of the Arco, Ida., project shown at Geneva.



HOW TO UN-CONTROL and thus explode a boiling water reactor—and the results—made a top paper. This view shows the explosion at its height.





Baldwin SR-4 System indicates and continuously totalizes ore loads in the crane cab (above). The operator has a continual check on the load being carried by the clamshell.

At Alabama State Docks this Heyl & Patterson crane...

unloads ore faster by using SR-4® automatic weighing system

Baldwin's "Packaged Precision Measurement" can cut your ore handling costs. That's been proved at the Alabama State Docks, Mobile, Alabama. There a Heyl & Patterson unloading crane is using Baldwin SR-4 load cells and indicator to weigh electrically clamshell buckets of ore.

This Baldwin SR-4 automatic weighing system benefits this user three ways:

1. **Faster handling:** The bucket does not have to be stopped to determine weight since its weight is being measured by two 20,000 pound load cells in the sheave block. More ore can be handled by the unloading equipment each shift, reducing handling costs.
2. **Easy operation:** A large indicator dial in front of the operator tells him when to add the weight on the totalizing counter. The indicator totalized the weights measured by two distant SR-4 Load Cells and zeroes out all but net weight of ore.
3. **Low maintenance:** SR-4 Load Cells have no moving parts to wear out. They are sealed against air-borne dust They are giving accurate, dependable service.

Baldwin SR-4 Load Cells can solve your weighing and force-measuring problems. Write for our *new* Bulletin 4301. It's loaded with detailed information on typical applications and instrumentation for these unique devices. It tells you how to use them for local or remote indication, recording, signaling or process control. Use coupon today!

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☐ #4304 (SR-4 Crane Scales)

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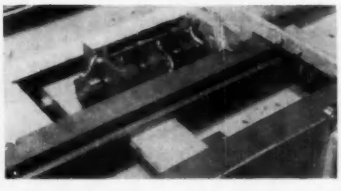
Feedback by Camera

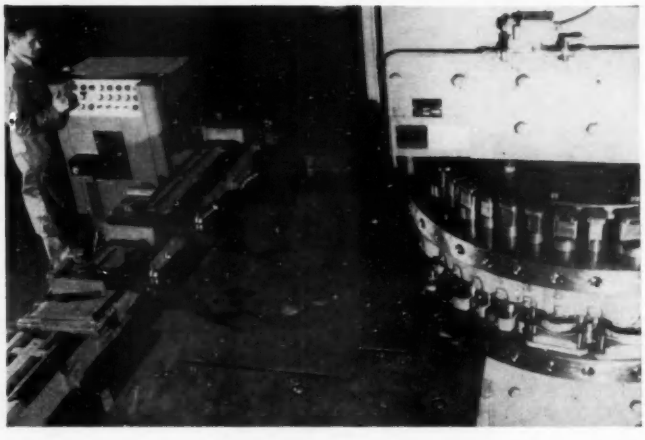
KNOW-HOW GOING ABROAD:

This mobile display of Mason-Nielan control demonstrators recently was shipped to Europe for a two-year tour of major plants there—a specific answer to CONTROL ENGINEERING'S June, 1955 Editorial, "Needed—Technicians Abroad".

GE's NEW DIGITAL POSITIONER:

The large photo shows the director console, which reads punched card instructions and positions the big punch press. The device shown below is the Selsyn pickup, which feeds back position to the control. These are the key components of General Electric's new entry into machine control. It is a fine example of gains in this field as described in the second part of Waldo Kliever's article on page 84 of this issue.





A RESPONSIVE AUDIENCE:

As two articles in this issue indicate (see pages 56 and 60) frequency response techniques can be a telling tool for the control engineer. Taylor Instruments Companies proved this when it conducted a symposium on "Frequency Response for Process Control" in Rochester, N. Y., last May. For a full week, thirty control engineers from all over the continent boned up on the subject. Take a look at the alert faces in this formal picture of the group and you'll see that it "took". Taylor's excellent course filled 660 pages of text. Watch for portions of it in future issues of CONTROL ENGINEERING.

TRANSISTOR-RADIO! G.E.'s new All-Transistor Portable, Model 675, made possible by H.F. transistor developed by G.E.

NOW—A FULL LINE OF G-E H.F. TRANSISTORS FOR ALL RADIO APPLICATIONS

New G-E H.F. PNP Transistors, 2N135, 2N136, 2N137, Complement the G-E 2N78 NPN

THIS new line of G-E High Frequency PNP Transistors offers immediate benefits to electronics manufacturers for use in RF and IF amplifier circuits. The new High Frequency designs, now in full production, were created specifically for use in radio circuits. The line provides minimum alpha cut-offs of 3 MC, 5 MC and 7 MC—coupled with a 5 ua maximum collector cut-off current. The result: all the high-gain and high-power advantages of other General Electric transistors, *plus* operating ranges extending from 3 to 15 MC depending on the transistor selected.

NOW IN COMMERCIAL RADIO CIRCUITS

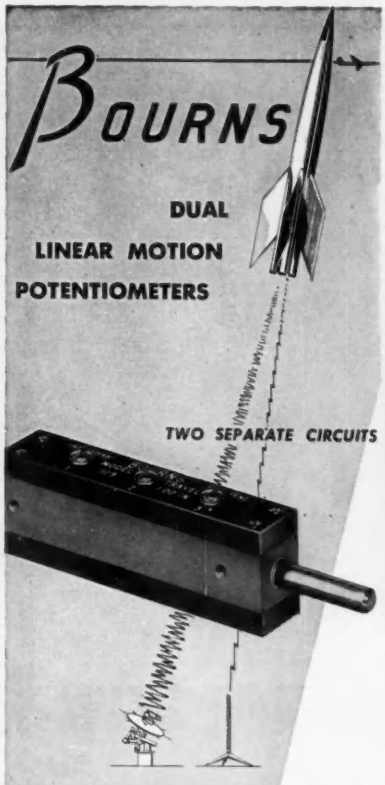
In the circuit above, the 2N136 is used as a converter—its 5 MC minimum alpha cut-off assures stable oscillator performance and high conversion gain. The 2N137 —with 7 MC minimum alpha cut-off—provides 33 db gain at 455 KC. The high frequency 2N135 offers a higher collector voltage rating for the second IF where it is needed. The 2N78 NPN transistor—originally designed for computer and RF circuitry—proved ideal as a power detector and audio amplifier to drive a 2N44 power output transistor with direct coupling.

PRODUCTION QUANTITIES AVAILABLE

General Electric's new high frequency line is in mass production now. Detailed characteristics and specifications of the G-E 2N135, 2N136, and 2N137 transistors may be obtained upon request. Your G-E Semiconductor specialist and our factory application engineers have the answers to your transistor radio circuit questions. Call them in, or write: *General Electric Co., Semiconductor Products, Section X99105, Electronics Park, Syracuse, N. Y.*

Progress Is Our Most Important Product

GENERAL ELECTRIC



FOR AIRCRAFT AND GENERAL INDUSTRY

Designed for precise instrumentation in automatic control circuits for aircraft, guided missiles and general industry, BOURNS linear motion potentiometers accurately translate mechanical position or movement into two independent signals . . . one signal often used for feed-back control and the other for telemetering.

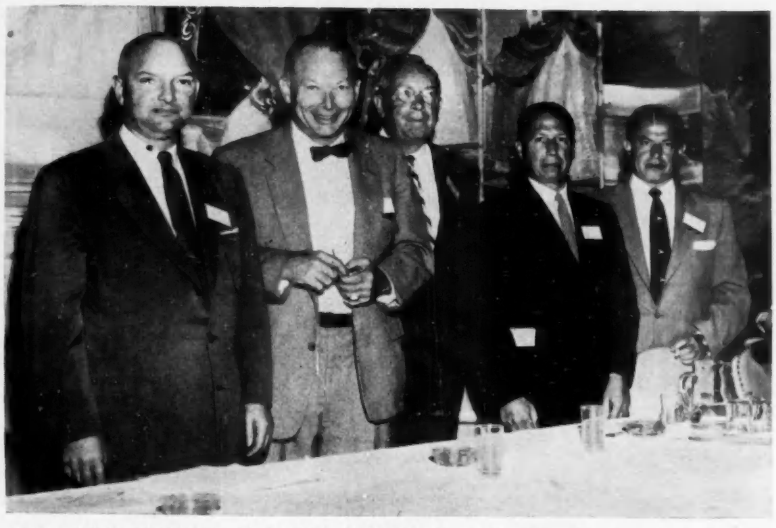
This dual instrument possesses all the advantages of two single potentiometers and in addition, saves space, weight and installation time. With this wire-wound potentiometer a resolution of .001 inch is obtainable in standard ranges from 1 to 6 inches.

BOURNS designs and manufactures other potentiometer instruments which measure gage pressure, differential pressure, altitude and acceleration.

BOURNS LABORATORIES

6135 Magnolia Avenue, Riverside, California

Technical Bulletin on request, Dept. 279



FIVE WHO SHOULD–AND DID–KNOW: Case histories of automatic production were described by this group* at the Electronics and Automatic Production Conference in San Francisco's Sheraton-Palace Hotel on Aug. 22.

Automation and Electronics Get A GOLDEN GATE REVIEW

By Eugene M. Grabbe
Special to Control Engineering

SAN FRANCISCO, Aug. 25—Powerful evidence that the West Coast intends to lead in the electronics and automatic control fields moved into focus these last few days with the more than 20,000 industry visitors who jammed this city's Civic Auditorium for the ninth annual Western Electronics Show and Conference. In fact, this intent loomed strong two days before the show opened, when 504 other representatives of business and industry arrived for a special symposium on Electronics and Automatic Production, held jointly by Stanford Research Institute and the National Industrial Conference Board.

The automation symposium stressed the need for the systems approach and teamwork in carrying out automation programs. L. K. M. Boelter, Dean of UCLA's Engineering Department, thoughtfully reviewed developments that led to engineering's concern "with the components of a system, rather than *the* system". D. E. Wooldridge, President of Ramo-Wooldridge Corp., stirred his audience by saying, "The lesson the government has learned in military electronics at a cost of many millions of dollars—that the integrated systems approach is the proper approach to complex systems—is strictly applicable in business and industry." He went on to point out that, because of this experience, "military people often have a more sophisticated or informed approach to systems than many business executives."

Control Engineering Cited

Speakers in later sessions emphasized the need for teamwork and a new approach in control education. Robert T. Keller, Vice President of Chrysler, described "the automatic and electronic field as rapidly developing into a separate area of endeavor with the control engineer as the expert." He cited CONTROL ENGINEERING as the clearing house for this new profession.

The 600 Wescon exhibits and 160 technical papers in the auditorium made this the second largest show of its kind ever held. Almost 200 of the booths were occupied by West Coast

*Left to right: Loren F. Jones, Manager of Operations Programming, Radio Corp. of America; Victor F. Hanson, Assistant Director, Experimental Station, E. I. du Pont de Nemours & Co.; L. A. Hyland, Vice President and General Manager, Hughes Aircraft Co.; W. K. Scott, Staff Engineer, Columbia-Geneva Steel Div., U. S. Steel Corp.; Robert T. Keller, Vice President, Chrysler Corp.

The ancient priests of Egypt were engineers whose great pyramid of Cheops was sextant, compass and slide rule—all in one. From sighting the Pole Star, to squaring the compass, to the mathematics of pi—it's all there in the pyramid of Gizeh.

flying pyramids

Wonder of the world for ages, Gizeh's pyramid was a fount of mathematical data—a tool to check measures, an aid to celestial navigation. Today's aircraft are "flying pyramids"—collecting and integrating instantaneous measurements for orientation and control. Kollsman activities cover these seven fields:

AIRCRAFT INSTRUMENTS
PRECISION CONTROLS
PRECISION COMPUTERS AND COMPONENTS
OPTICAL COMPONENTS AND SYSTEMS
RADIO COMMUNICATIONS AND NAVIGATION EQUIPMENT
MOTORS AND SYNCHROS
INSTRUMENTS FOR SIMULATED FLIGHT TRAINERS

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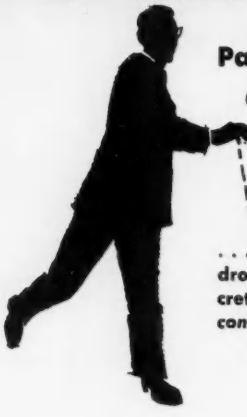
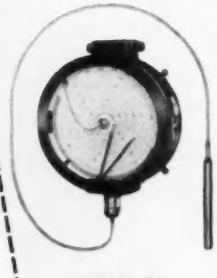


Partlow Temperature Controls need no babying"

. . . so tough in fact that you can drop Partlow Controls on a concrete floor — *without upsetting control accuracy!*

DOES YOUR PROCESS require precise temperature control of gas, liquids or solids in the —30°F to 1200°F range? If "yes", there's a guaranteed Partlow Control to do your job *better* than complicated, less rugged thermocouples and other types — *and at lower cost!* Send us your problem. Partlow, specializing in temperature, designs controls for all types of new and existing applications. Here are five basic Partlow advantages:

1. **DIRECT-ACTING** hermetically sealed Mercury Bulb instrumentation. Positive, precise, sensitive — never temperamental.
2. **INTERCHANGEABLE ELEMENTS** — for quick, easy field replacement.
3. **ACCURATE CALIBRATION** — conservatively, within 1% of scale range.
4. **LONG LIFE** — thick-walled capillaries and seamless tubing assure almost indefinite life.
5. **LOW INITIAL COST** . . . low upkeep — few moving parts — no need for compensators.



MODEL RS
Recording Controller operates fuel valves or relays to start and stop combustion systems or electric heater loads.

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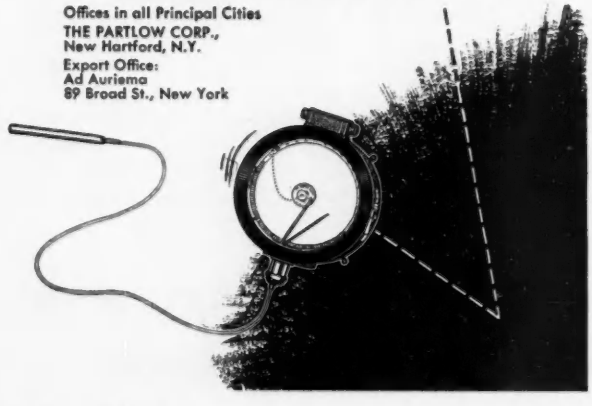


WHAT'S NEW

manufacturing firms—another indication that the local industry, which now does 19 per cent of the nation's electronics business, is expected to make notable gains.

Technical sessions on "Industrial Electronics and Nuclear Engineering", "Electronic Instrumentation in Aircraft Development", "Automatic Controls", and "Computers" demonstrated the keen interest of these western firms in applying new developments to industrial use. Some control high spots in the sessions were:

► Martin Packard of Varian Associates, Palo Alto, in a paper entitled "Geophysical and Industrial Applications of NMR", described the first commercial use of nuclear magnetic resonance (NMR). An instrument for measuring the earth's magnetic field accurately to within 1/25,000 is being flown in routine mapping in geophysical prospecting. A lab model is also being used to analyze chemical streams.

► Donald Dynes of Edwards Air Force Base discussed control problems in "Rocket Engine Testing". He noted that in going from zero to maximum thrust in 250 millisec and at powers up to 2×10^6 hp, the human operator is 50 times too slow to control the power plant. Hence automatic control is needed to prevent damage or destruction. One unique unit counts fuel line high frequency pressure pulsations—associated with combustion instability—which could cause blow up. If 75 cycles are counted, fuel is shut off.

► Great interest in non-linear servomechanism problems was shown by the large audience that turned out for the session sponsored by the Professional Group on Automatic Control (*Ed. Note: Reporter Grabbe was Chairman!*). Each of the five papers described experiments that verified non-linear theoretical solutions.

All Around the Business Loop

► **Panellit, Inc.**, is fostering in Great Britain an English Panellit company which, as manufacturer and supplier, will be engaged in a three-part operation that includes sub-contracting parts and assemblies, and installing automatic devices and systems. Others in the triumvirate are **Hall Telephone Accessories** and **James Gordon & Co.**, an engineering company that installs automatic controls. Hall Telephone has acquired the Gordon company, which, in turn, is responsible for forming Panellit's English counterpart.

The Standard of Comparison

New engineering concepts have resulted in the Beckman Infra-Red Spectrophotometer, Model IR 3, most advanced and accurate laboratory investigation equipment of its kind ever built.

A Berlant Magnetic Tape recorder is used to "remember" slit positions and wave length values of a standardizing sample, then "play back" this information to accurately control slit width and wave length values within a limit of .001 micron. A unique Beckman development, the memory system by magnetic tape control results in an absolute analysis accuracy of ¼%, compared to the best previous of 3% from split beam comparison instruments. Lee Cahn, a chief project engineer of Beckman division, Beckman Instruments, Inc., explains the inner workings of this amazingly accurate device to Bert Berlant, president of Berlant Instruments.

The reasons why the Berlant tape recorder was chosen as the "standard of comparison" are the qualities that have made Berlant Broadcast and Berlant Automatic Recorders the most widely specified recorders for radio stations and other professional uses.

In less than a year since it was introduced, this professional recorder has won universal acceptance for highest performance and dependability. Berlant recorders feature a flexibility and versatility unmatched by any other recorder on the market, regardless of cost.

If you have a requirement for a magnetic tape recorder in the audio field, a Berlant-Concertone franchised distributor in your neighborhood is prepared to render you guaranteed satisfaction... at a comparatively low cost!

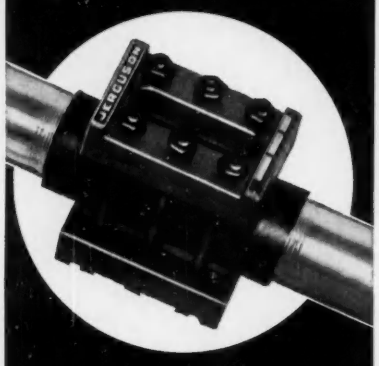
If you have a special magnetic recording requirement in instrumentation or industrial usage, call or write to Berlant *Recordata Division* for information on specialized equipment to satisfy your needs.

BERLANT INSTRUMENTS
4917 West Jefferson Boulevard
Dept. O21, Los Angeles 16, California

THIS IS NO. 4 IN A SERIES OF FIELD REPORTS.

Manufacturers of Concertone... world's foremost high fidelity recorders and accessories.

NEW . . .
Jerguson Sight Flow Indicators



easily and inexpensively installed to show movement of liquid in pipe lines

Here is a new line of Sight Flow Indicators . . . easily and inexpensively installed in any new or existing pipe line ½" to 2" N.P.T.

The special design of these new indicators results in a turbulence in the flow of liquid, making it easily visible. Several types of indicating vanes, installed within the chamber, may also be furnished, according to variable conditions of rate of flow and viscosity of liquid. For indication of minute flows, small Sight Flow Indicators with a rotating vertical rising ball are available.

Jerguson Sight Flow Indicators are soundly designed, carefully made, and are backed up by a company with over 40 years experience in the field. Available in Transparent and Reflex types, in a wide variety of materials and linings, and with Wedge Type Illuminators, Haveg Chambers, Non-Frosting Glasses, or other special construction.

If you have a problem of viewing the flow of liquid in a pipe line, it will pay you to investigate the new Jerguson Sight Flow Indicators today. Send us your requirements or write for Data Unit.

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Pétrole Service, Paris, France

WHAT'S NEW

FIRST ACROSS THE BORDER for Robertshaw-Fulton Controls Co. is this new plant opened at Toronto by Robertshaw-Fulton Controls (Canada) Ltd. The plant will supply automatic controls for home appliances to manufacturers in Canada and the British Commonwealth.

GIANNINI'S NEW HOME for its Datex Div. (see What's New, July, 1955, page 26) is located at 1307 South Myrtle Avenue, Monrovia, Calif. The 15,000 sq ft of floor space are laid out expressly for instrument manufacture. Future expansion is provided for.

▶With space for engineering personnel tripled in Chicago, **Raytheon Mfg. Co.** is looking for recruits for its expanded **Equipment Operations** facilities there. The Chicago division will concentrate on research and engineering development programs in electronic and infrared equipment.

▶**Erie Resistor Corp.'s** new **Electro-Mechanical Div.** has been given the job of engineering and producing the company's line of special electronic assemblies. The division's exclusive handling of these orders will be on a custom basis.

▶**Micro Switch Div. of Minneapolis-Honeywell Regulator Co.** has purchased the Freeport, Ill., factory that it has leased for several years. The factory's 300,000 sq ft bring to more than 500,000 sq ft the amount of space owned by Micro Switch in Freeport.

▶Recognizing the importance of the West Coast in the aviation industry, **Sperry Rand Corp.'s Ford Instrument Co.** has opened an office at 260 South Beverly Drive, Beverly Hills, Calif. Edward F. Manion, liaison engineer on Air Force contracts, is in charge of the office. He will serve the coast's airframe manufacturers and represent Ford to its major customers.

▶**Magnatron Corp. of America** has started construction in San Diego of a small research laboratory and factory. The new company will begin production in 1956 of power electronic control equipment for **Continental Can Co.** and other companies. Magnatron's president and chairman is Alfred Vang, formerly consulting engineer for Continental Can.

▶With the acquisition of **Robey Motor Co.** of Culver City, Calif., **J. B. Rea Co.** of Santa Monica is closer to realizing its goal of building its own complete automatic control systems. The new **Robey Div.**, which will produce gyroscopes, blowers, and miniature motors for aircraft and guided missiles, will be managed by Oscar Robey, founder of the acquired company.

▶**Perkin-Elmer** has opened, in Pasadena, Calif., a regional sales office to

FOR HIGH CURRENT

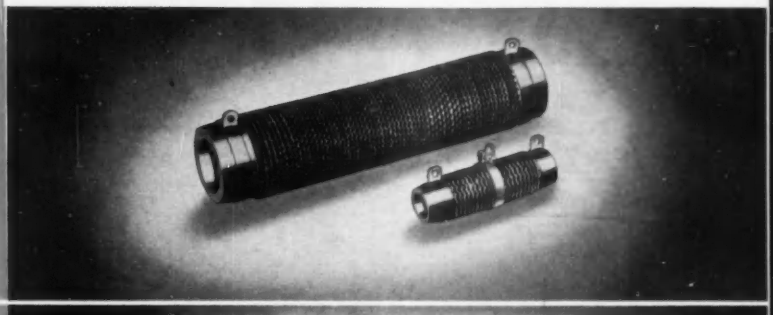
LOW RESISTANCE APPLICATIONS . . .

OHMITE® *Power Type* RESISTORS

CORRIB®

Vitreous-Enameled, Corrugated-Ribbon Type

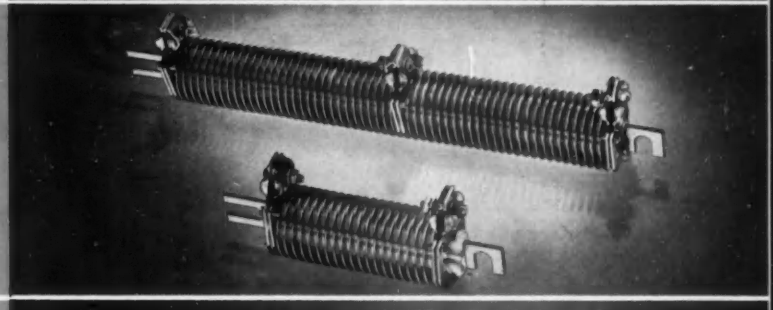
Special Ohmite vitreous enamel locks the edge-wound ribbon alloy to a sturdy ceramic core. Fixed, tapped, and adjustable types. Available in 22 sizes from 90 to 1500 watts. Resistance values range from .04 to 70 ohms.



POWR-RIB®

Edgewound-Ribbon Type

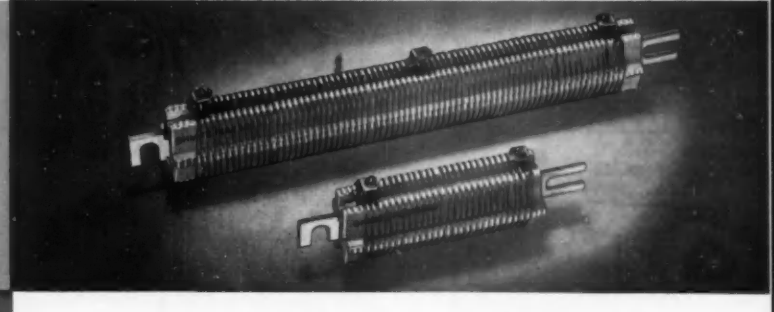
Has a heavy ribbon of resistance alloy, edge-wound on a ceramic core. Core is sectionalized for flexibility and shock resistance. Terminals and brackets are plated to prevent oxidation. Four sizes in resistances from .043 to 1.6 ohms; and from 24 to 95 amperes.



POWR-RIB®

Round-Wire Type

Similar in construction to Ribbon-Wire type shown above, but with round resistance wire. Sturdy ceramic core is made in two to five sections. Available in four sizes. Resistance values from .69 to 25 ohms. Current ratings from 5.1 to 18.4 amperes.



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NEW
MINIATURE
Low Capacitance
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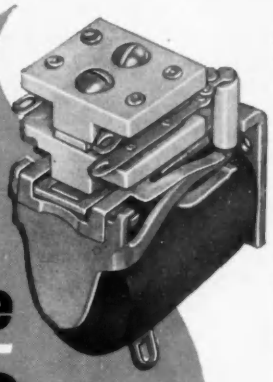

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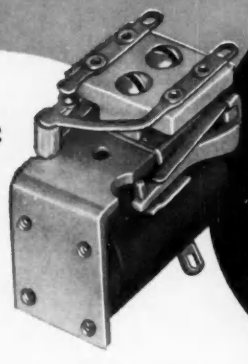

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SWITCHES MOUNTED
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CERAMIC SEPARATORS

Capacitance (with 1 Form "A" switch):
Capacitance between open contacts .75 mmfd;
Capacitance between closed contacts 2.0 mmfd;
Capacitance from contact to ground 1.25 mmfd.

Coil Resistance: Up to 6500 ohms (No. 44 AWG wire).

Contact Rating: 3 amps. @ 28 VDC max. Suitable for low level audio or r.f. loads. Contact material dependent on application.

Contact Combination: Standard, up to 1 Form "C".

Shock: Meets requirements of MIL-R-5757B.

Vibration: 10G up to 500 CPS.

Size: 23/32" wide, 15/32" long, 13/16" high with 1 Form C.

Applications: For guided missiles, h.f. communications equipment, etc.

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WHAT'S NEW

service the western and northwestern states. Personnel include Winston C. Loe (process control equipment), Thomas A. Guerin (laboratory instruments), and Albert W. Ehm, who will be service engineer.

► Three electronic data-processing systems built by **Consolidated Engineering Corp.** are destined for the Air Force's **Arnold Engineering Development Center** at Tullahoma, Tenn. Contracts totalling $573,000 call for a fully automatic wind tunnel system that will measure pressures on jet engines and air-foil sections; a system that will measure force and moments on aerodynamic and propulsion models; and a data-processing system that will convert electrical measurements of temperature, strain, pressure, and acceleration into a form that can be handled by a computer.

► This fall **Westinghouse Air Brake Co.'s Union Switch & Signal Div.** will deliver the control equipment that fulfills a contract with **Gulf Interstate Gas Co.,** which has earmarked its Stanton, Ky., compressor station for remote control from Clementsville, Ky., about 90 miles away.

Important Moves by Key People

► The man who supervised the installation of the instrumentation for the control of the reactor in the Brookhaven National Laboratory in 1949 has been appointed consultant on nuclear energy by the Brown Instrument Div. of Minneapolis-Honeywell Regulator Co. He is **Dr. Truman S. Gray,** associate professor of engineering electronics at MIT, secretary of the Committee on Nucleonics of the American Institute of Electrical Engineers, and formerly a consultant to the Army Quartermaster Corp.

► **Alois Berny Essex** fills the new position of Administrative Engineer of Ford Instrument Co., Div of Sperry Rand Corp. The former project supervisor on Army fire control equipment holds eight patents on guided missile and anti-aircraft developments. He will report directly to **Henry F. McKenney,** Chief Engineer.

► As the new Chief Engineer of the Semiconductor Products Div. of Texas Instruments, Inc., **Harry L. Owens** will steer development and engineering of germanium and silicon semiconductor products. Owens, co-author of *Transistors, Theory and Applications,* was formerly Chief of the Solid State De-

another outstanding feature . . . REEVES

REAC 400

ANALOG COMPUTER

new HIGH SPEED SERVOS

- Bandwidth over 50 cps.
- Velocity 1500 v/sec.
- Plug-in turrets for function generation

New **BUILDING-BLOCK CONSTRUCTION**

Permits assembly of computer elements in any desired combination to do particular job or expand existing installation.

New **CONVENIENT PATCHBAY**

Available in units of 1632, 3264 or 4896 holes for maximum flexibility. Patchboard changes possible during operation.

New **POWERFUL AMPLIFIERS**

Noise less than 3 mv rms **in cabinet.** Phase shift 0.075° @ 100 cps. **in cabinet.** Bandwidth over 10 KC **in cabinet.**

New **HIGH SPEED RESOLVERS**

Vastly improved dynamic performance . . . 35-cycle bandwidth.

★ **Six gang multiplying potentiometers.** Accuracy equivalent to 0.1% linearity potentiometers (over-all multiplying accuracy 0.2% *including mechanical non-linearities).* Two gangs tapped for function generation.

★ **Two front panel plug-in turrets** for padding or feeding voltages into the tapped pots for function generation. Turrets may be stored for future use.

★ **High Speed** — Velocity 1500 v/sec.

★ **Long Life** — Carbon film potentiometer gives exceptionally long life even at high velocities.

★ **Superior Frequency Response:**
Maximum amplitude rise 1.4 @ 40 cps.
Bandwidth over 50 cps.
Dynamic error less than 0.5% of input @ 2 cps.!
Phase shift less than 0.3° @ 3 cps.!

★ **Exceptional low speed performance too** — Typical tracking error less than 0.05 volts maximum for ramp input as low as 0.01 v/sec.

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A HARTFORD
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GIVES THIS NEW
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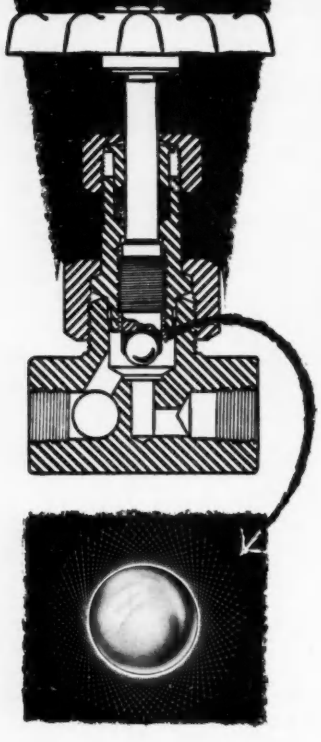

This new Foxboro universal valve—for liquids, gas or steam—can't leak, practically never wears out . . . yet costs little or no more than an ordinary valve. The seating arrangement is radically new. Replacing the usual disc or plug, a ¼" Hartford free-rolling precision stainless steel ball provides a positive new seating surface at every valve closing . . . insures long life . . . leak-proof seal . . . and positive shut-off.

It is another of the thousands of ways Hartford balls and bearings are helping manufacturers to improve their products. Hartford engineers will gladly assist you with any problem on the application of balls, retainers or bearings made to your specifications.

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WHAT'S NEW

Dr. T. S. Gray

Ford's Essex

TIC's Owens

Ampex's Selsted

Poly's DiToro

Clark's Wycoff

vices branch of the Army Signal Corps Engineering Laboratories at Fort Monmouth, N. J.

▶J. B. Rea Co. has made two important changes in computer personnel: **G. W. Anderson,** formerly head of the Analog Computing Service, appointed manager of the Analog Simulation Development Section, and **James E. Murrin,** formerly a mathematician in the Aerial Measurement Laboratory of Northwestern University, appointed to succeed Anderson. Murrin's area will be computing facilities for industry, Anderson's development of analog computer devices, special purpose computers, and analog control systems.

▶A foremost authority on radar has been named manager of the Equipment Engineering Div. of Raytheon Mfg. Co. He is **Fritz A. Gross,** who joined Raytheon in 1933 and most recently was Chief Engineer of the division. Gross played a key role in the wartime development of the first microwave shipboard radar, the "SG", and in Raytheon's method of mass-producing the magnetron, heart of modern radar. He was in charge of the post-war group that designed the "Mariners Pathfinder" radar for commercial vessels.

▶**Walter T. Selsted** has been appointed director of Ampex Corp.'s new Research Dept., into which has been channeled research activities formerly carried on by engineers in the company's Audio and Instrumentation Div. Target of study in the new division will be basic principles in magnetic recording.

▶New Chief Electronic Engineer of Polytechnic Research & Development Co. is **Dr. Michael J. DiToro,** whose impressive experience in electronics includes a period as Associate Director of the Microwave Research Institute of Polytechnic Institute of Brooklyn.

▶**H. R. Shaw** has been named Senior Assistant to the Director of the Electro-Mechanical Engineering Dept. in the Downey, Calif., plant of North American Aviation, Inc. The department, a part of the company's Missile and Control Equipment organization, develops automatic guidance systems and instrumentation.

▶**Dr. Clarence M. Ablow** and **Dr. Otto Heinz** have joined the staff of Stanford Research Institute, the first as senior research mathematician in the Radio System Laboratory, and the second as research engineer in the Antenna Laboratory. Ablow formerly was with Boeing Airplane Co. and Heinz was with Bell Telephone Laboratories and the University of California Radiation Laboratory, Berkeley.

▶**David C. Wycoff** has been named to the new position of manager of Clark Controller Co.'s Product Adaptation

For All Types of Systems...

BS&B Type 86 Diaphragm Control Valve Is The "Workhorse" Of The Industry!

Controls Flow For:
Temperature
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Liquid Level

Handles:
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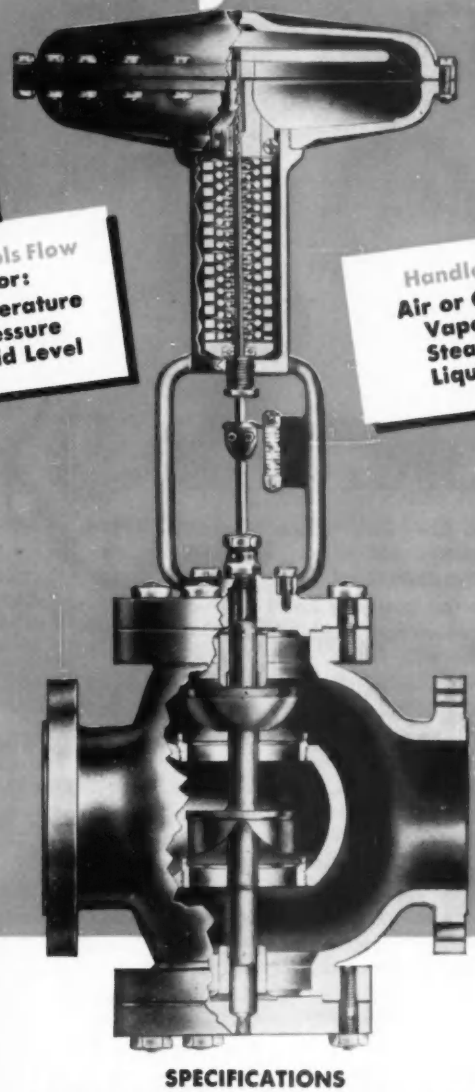


- ✓ Wide Range of Application
- ✓ Wide Selection of Trim Characteristics
- ✓ Wide Rangeability
- ✓ Double Port—½" to 16"
- ✓ Single Port—½" to 8"
- ✓ Reversible Inner Valves

Take Both The GUESS And The WORK Out Of Controls Sizing For Liquid, Steam And Gas Applications By Using BS&B's New And Exclusive Sizing Method, As Set Forth In Our New "Controls Sizing Manual." Available On Request From Your BS&B Representative.

EFFICIENCY
OVER 60 YEARS
BS&B
RELIABILITY
ANOTHER EXAMPLE OF PRODUCT LEADERSHIP

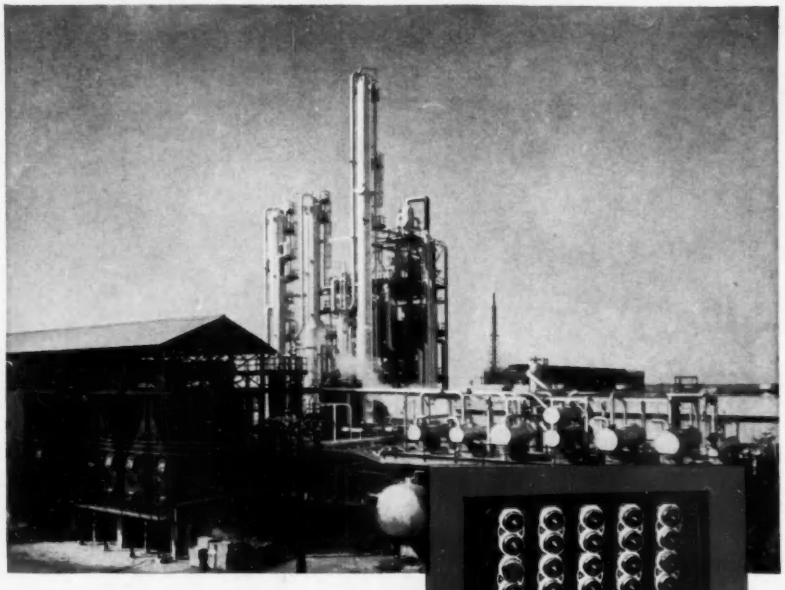
SPECIFICATIONS

Body Size: Double Port, ½" to 16". Single Port, ½" to 8"
Body Style: Screwed Globe and Flanged Globe.
Pressure Range: 125 to 5,000 lbs. within body size limits.
Temperature: Up to 800° F.
Diaphragm Pressure: 3 to 15 lbs., standard.
Material: Body—high tensile cast iron, electric cast steel, or special alloys. Trim—bronze or 18-8 stainless steel or special alloys.

If You'd Like More Information, Contact Your Nearest BS&B Representative, Or Write To...

BLACK, SIVALLS & BRYSON, INC.
Controls Division, Dept. 4-ES10
7500 East 12th Street
Kansas City 26, Missouri

FIELDEN Scanner Sets New Standards for Flexibility, Speed and Maintenance



With the new Fielden Scanner, process plants are now combining custom-tailored scanning systems with the utmost ease of maintenance and operating safety.

This unit is amazingly simple, yet offers a choice of (1) automatic or manual operation, (2) scanning cycles, and (3) scanning speeds. Points can be identified in several ways, and can operate signals, indicators, recorders or controllers. For on-off control, the newly engineered straight-line direct-reading slidewires conserve space and permit easy comparison of control points. Up to 30 slidewires can be mounted on the door of the case.

Other features include a slide-out chassis and top-pivoted relays that expose all components for easy maintenance. Components themselves are kept to a minimum (only 2 tubes). And for maximum operating safety, the unit continuously checks components, sensing elements, and scanning cycle periods.

The simplified Fielden Scanner can be used for temperature, level, pressure, and many other variables. Send the coupon today.

Robertshaw-Fulton
CONTROLS COMPANY

FIELDEN INSTRUMENT DIVISION
Dept. S, 2920 N. 4th St., Philadelphia 33, Pa.

- ☐ Please send bulletins on:
- ☐ Fielden Null-Balance Recorders
- ☐ TEKTOLOG Recorder-Controllers
- ☐ New Fielden Scanner
- ☐ TEKTOR Level Limit Control
- ☐ TELSTOR Continuous Level Indicator

NAME_____ TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE_____ STATE_____

WHAT'S NEW

Dept., an arm of the New Products Div. Wycoff has been manager of the company's Experimental Laboratory.

► Several relay specialists have teamed up at The Phaostron Co. to design and guide manufacture of sub-miniature relays for transistor circuitry. They are: Vice-president **E. W. Carson,** Chief Engineer **Philip Chamberlain,** Chief Research Engineer **Chester R. Rhodes,** Research Engineer **Clarence H. Dibble,** Project Engineer **John Q. Adams,** Methods Engineer **C. A. Hale,** and Test Engineer **Roy C. Johnston.** Adams, Hale, and Johnston are new additions to Phaostron.

► Operation of the Berkeley Div. of Beckman Instruments, Inc., has been placed in the hands of **Donald C. Duncan.** This brings to three the number of divisions under Duncan, the other two being Helipot and Arga. New manager of the Berkeley Div. is **Thomas Allinson,** formerly sales manager.

► **Donald Tuomi,** appointed research engineer at the Edison Research Laboratory of Thomas A. Edison, Inc., has had experience with Baird Associates, MIT, Ohio State University's Research Foundation, Columbia University, and Carbide & Carbon Chemicals Co.

► Neely Enterprises, electronic manufacturers' representatives, has promoted **William E. Zinky,** coordination engineer, to field engineer in Los Angeles, and appointed **Philip E. Goodrich** and **B. L. Sadler** coordinating engineers there.

► **John E. Mossman,** formerly president of Phillips Control Corp., has been elected president of The Industrial Electronics Co. Industrial Electronics recently acquired Monitor Controls Co. and is operating it as a division.

► **John R. Curran,** who joined Hammel-Dahl Co. in 1949 and most recently was Director of Engineering, has been elected vice-president.

► CGS Laboratories, Inc., has elected **William R. Smith-Vaniz** vice-president. **Smith-Vaniz,** formerly assistant chief engineer, was largely responsible for the first all-electronic computer that converts Morse code signals into electric pulses for a standard teleprinter.

► **Dr. F. Ralph Kotter** has left an assistant professorship at MIT to rejoin the National Bureau of Standards as a member of the Resistance and Reaction Section of the Electricity and Electronics Div. He will plan and

HANCOCK

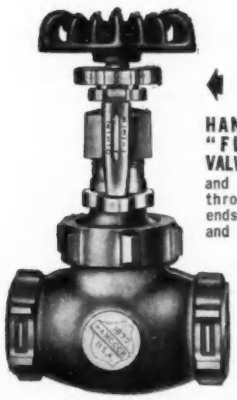
"FLOCONTROL" VALVES GIVE YOU PIN/POINT CONTROL

Here's manual control of flow, temperature and pressure that's really precise. Hancock "Flocontrol" Valves, with micrometer dial and pointer mounted on the bonnet, permit settings to within 1/100th turn of the handwheel! Equally important, any setting can be duplicated easily, perfectly — any time.

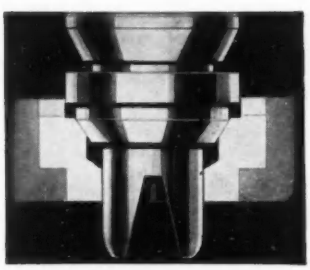
Hancock "Flocontrol" "3 in 1" design gives you the advantages of a variable orifice, plus a shut-off, plus an index... all in "one package." Bronze and steel types are available. Both have a scientifically designed V-Port valve disc that *compels proportional flow throughout the entire lift of the valve stem.* The shut-off seating surface is entirely removed and separate from the controlling V-Ports. Super-finished "500 Brinell" stainless steel seats and discs minimize the effects of wire-drawing and steam cutting.

For fine throttling control and proportional flow... for greatest efficiency, lowest operating costs — install strong, dependable Hancock "Flocontrol" Valves in your lines. Your nearby Hancock Distributor will gladly give you full details.

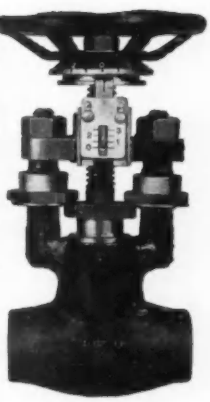
When Hancocks go in, valve costs go down



HANCOCK BRONZE "FLOCONTROL" VALVES. **Types:** Globe and Angle. **Sizes:** ¼" through 2". Screwed ends. Available in 150# and 300# Series.



VALVE SEAT AND V-PORT DISC fully closed. As the valve is opened proportional flow is gradually increased. The Hancock "Flocontrol" Valve has straight-line flow. Its regulation does not depend on the short-wearing, fine threads common to a needle valve.



HANCOCK 600# STEEL "FLOCONTROL" WELDVALVES. **Types:** Globe and Angle. Outside Screw and Yoke. **Sizes:** ¼" through 4". Screwed, Socket Welding and Flanged Ends. Available with 150#, 300# and 600# Series Flanges.

YOUR LOCAL INDUSTRIAL SUPPLY DISTRIBUTOR is as close as your nearest telephone. His 24-hour emergency service and large stocks of the finest supply items simplify your purchasing and save money for you.

HANCOCK VALVES

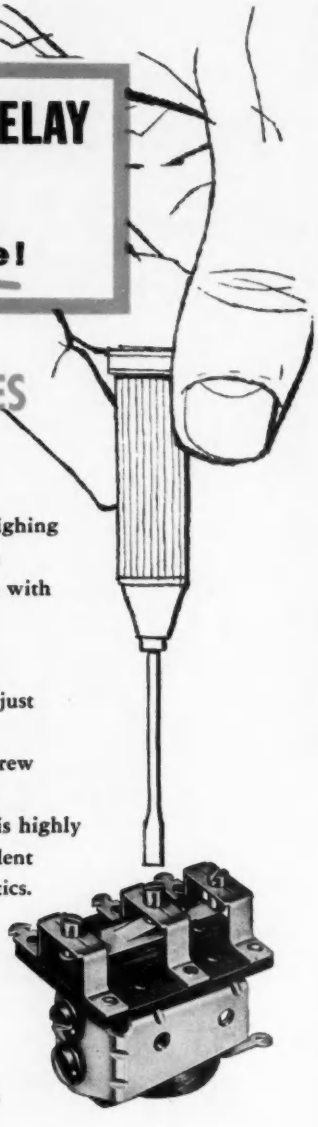
A product of **MANNING, MAXWELL & MOORE, INC.** Watertown 72, Massachusetts

MAKERS OF 'HANCOCK' VALVES, 'ASHCROFT' GAUGES, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN' INDUSTRIAL INSTRUMENTS, AIRCRAFT PRODUCTS. BUILDERS OF "SHAW-BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.

UNIQUE SENSITIVE RELAY

incredibly small, lightweight and adjustable!

ADVANCE "SO" SERIES



Here for the first time is a sensitive relay only 1-7/32"x 1-1/8"x 1-1/4"... weighing only 1-1/2 ounces, and adjustable over a wide range. You get much more latitude with this relay in designing for tiny areas.

The Advance "SO" is set at the factory to operate on 10 milliwatts. User can adjust it down to 2 milliwatts, or any desired pick-up or drop-out, by means of fine screw contacts. A balanced armature provides extremely sensitive operation. The unit is highly efficient, ruggedly built, and offers excellent shock and vibration-resistant characteristics.

Contact arrangement is SPDT. Coil resistances: 4000, 6500 and 10,000 ohms. Life expectancy: 250,000 operations. Available in open types... dust-tight or hermetically sealed enclosures. Now in quantity production. Advance "SO" relays are priced amazingly low. Write for literature.

Coil Resistance	Pick Up Voltage	Pick Up Current	Drop Out Voltage	Drop Out Current	Max. Coil Voltage for Continuous Duty	Overtravel	Contact Gap
4000	6.4 V	1.6 MA	3.2 V	.8 MA	110 V	.0015	.002/.003
6500	8.1 V	1.25 MA	3.9 V	.6 MA	140 V	.0015	.002/.003
10,000	10 V	1 MA	5 V	.5 MA	175 V	.0015	.002/.003

ADVANCE ELECTRIC AND RELAY CO.

ADVANCE RELAYS

2435 N. NAOMI STREET, BURBANK, CALIF.

AN ELGIN NATIONAL WATCH COMPANY AFFILIATE

WHAT'S NEW

direct maintenance of U. S. primary standards of inductance and capacitance. Prior to 1947 Kotter was in electrical ordnance work at the bureau.

▶ **Ed McCarthy** has been appointed sales representative in Southern California for Perkin Engineering Corp.

▶ **Baird Associates, Inc.,** has named sales engineering representatives in Hollywood, Calif.; Waltham, Mass.; Washington, D. C.; Chicago; Dayton, Ohio; Arnprior, Canada; Great Neck, N. Y.; and New York City. The New York representative, Ad. Auriema, Inc., is export agent for all areas of the world except Canada.

INSTITUTIONAL DOINGS

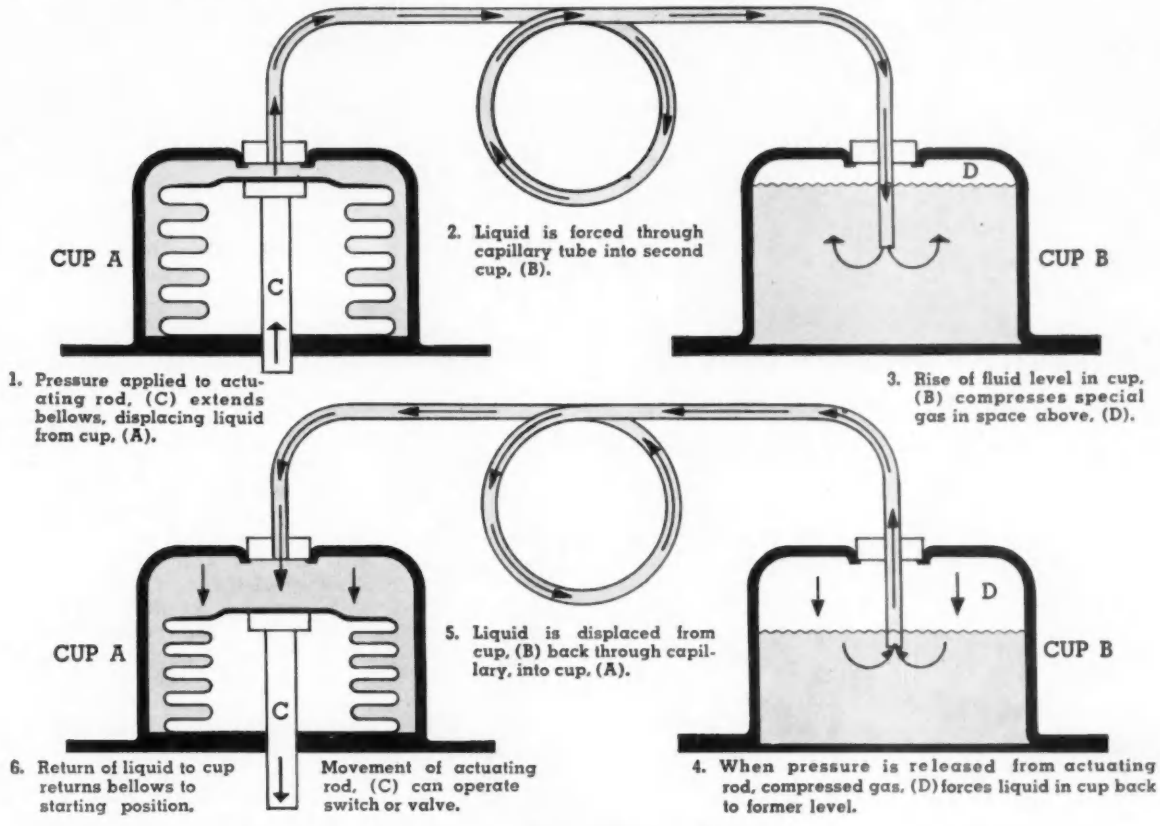
ORSA Premiers West Coast

When Operations Research Society of America held its seventh annual meeting, (the first on the West Coast), Aug. 15-17, it hit the jackpot: over 500, or more than one-half the total membership (now about 1,000 scientists) attended. It was the largest meeting to date for this growing society. While papers ran the gamut from OR applied to sales management through strategic weapons, our West Coast consultant, Dr. Eugene Grabbe, writes, "Not too much new material was actually presented at the conference. This is a very active field, secrecy reigns, and speakers frequently end up talking about what the other fellow is doing. However, there were some good papers on military systems problems. And Professor Howard Aiken of Harvard Computation Lab made an excellent address on the subject of Business Data Processing. He pointed out that it took 100 megabucks and 10 years to bring scientific computing machines to the present status. The results have been gratifying, but we can look to another large expenditure before business machines reach the optimum stage of development." Gene closed his letter with this thought: "The Operations Research groups in this country are growing and the subject includes a range of control problems. They contain many people who are interested in optimizing processes in military as well as industrial and business systems. This is certainly within the orbit of control engineering."

Mobilizing on Systems

One of the first conferences on the

How To Provide For Time-Delay Action With A Low Cost Bellows Device


CUP A
C
D
CUP B
1. Pressure applied to actuating rod, (C) extends bellows, displacing liquid from cup, (A).
2. Liquid is forced through capillary tube into second cup, (B).
3. Rise of fluid level in cup, (B) compresses special gas in space above, (D).
4. When pressure is released from actuating rod, compressed gas, (D) forces liquid in cup back to former level.
5. Liquid is displaced from cup, (B) back through capillary, into cup, (A).
6. Return of liquid to cup returns bellows to starting position.
Movement of actuating rod, (C) can operate switch or valve.

Simple Cup-and-Capillary unit operates hydraulically . . . provides delay times up to two minutes!

Time delay action can be accomplished with numerous devices. Electronic delay lines will provide delay times measured in microseconds. Electrical means such as relay circuits or motor powered timers, thermal means such as resistance wound bi-metallic strips and mechanical devices such as clock escapement mechanisms offer a wide selection of delay times.

Hydraulic devices, however, utilizing the movement of a flexible metallic bellows provide distinct advantages in many applications. Unlike either the electronic or electrical devices, bellows devices require no outside power. Unlike mechanical arrangements there are no springs, no moving parts, no mechanical linkage to break or get out of adjustment.

As indicated in the main illustration, the Clifford time delay unit consists of a standard bellows cup assembly connected by a capillary tube with another cup which forms an air tight chamber. Except for the inside of the bellows, the cup assembly (A) is completely filled with a liquid selected for the application. Cup (B) contains a measured amount of the liquid and the space above contains a special gas which is insoluble in the liquid. The capillary opening is so positioned that it terminates under the liquid and the gas is permanently trapped in the cup. An actuating rod is attached to the bellows in cup A.

Pressure applied to the rod extends the bellows, displacing the liquid from cup A, through the capillary to cup B. The rise in level in cup B compresses the gas temporarily and when pressure on the actuating rod is released, the compressed gas drives the liquid out of cup B back through the capillary and into cup A. With the return of the liquid, the bellows contracts and the resulting thrust of the rod can actuate switches or valves.

Delay interval is determined either by the time needed to displace the liquid from cup A to cup B or by the time necessary for the liquid to flow back into cup A and return the bellows to its original position. A filling liquid is selected whose viscosity remains essentially constant over the ambient temperature range to which the unit will be subjected. The hermetically sealed construction of the Clifford unit completely protects it from contaminants which tend to affect the time constant in units not so protected.

Standard units available. The Clifford Manufacturing Company can furnish standard units in production quantities having delay times of any selected period from one-quarter second to two minutes. Correct delay interval for the application can be obtained by selecting a suitable length and bore of capillary.

For appropriate units for your application, please send complete details covering: time constant required, force, ambient temperatures encountered and whether delay time is to be on forward or reverse stroke. **Clifford Manufacturing Company, 152 Grove St., Waltham 54, Mass.** *Division of Standard Thomson Corporation.* 7-5-67

Unit consists of two cup assemblies with appropriate length of capillary. It offers compact, rugged, hermetically sealed, low-cost design convenient for mounting. Time delay can be arranged for any interval from one-quarter second to two minutes and delay action can be on either the forward or return stroke.

HYDRON
METAL BELLOWS
CLIFFORD
MANUFACTURING CO.
WALTHAM, MASS.
DIVISION OF STANDARD-THOMSON CORP.
HEAT EXCHANGERS

Here is the new
GAMEWELL
Miniature Sine-Cosine Potentiometer

This miniature version of the conventional RL-11 and RL-14 sinusoidal potentiometers is 1 1/16" diameter x 1 1/16" long.

Functions of this new Gamewell Precision Potentiometer are accurately and smoothly developed. Four brush contacts move over a uniformly wound rectangular card and pick off output voltages that are proportional to the sine and cosine of the input angle at speeds up to 60 RPM. Standard resistance value is 18K, but resistance from 4K to 25K can be supplied. Accuracy at higher values is ±1%. Power rating: 1 watt ±40°C.

THE GAMEWELL COMPANY
NEWTON UPPER FALLS 64, MASS.
In Canada: Northern Electric Co., Ltd.

For information about this new sine-cosine Gamewell Potentiometer, write today.

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systems engineering approach in automatic control—and certainly the most sizable and well-rounded—took place on the campus of Purdue University July 25-27. The three-day program attracted control engineers from both processing and hardgoods manufacturing plants. The papers, primarily tutorial in content, dealt with such subjects as applying servo and network theory to process control and analog computing in systems analysis. CONTROL ENGINEERING's Bill Vannah, long an outspoken champion of the "systems cause", launched the conference with a review of "Milestones in Industrial Control Systems Engineering". Bill described the important developments of the pre-frequency-response era, unshrouded some of the significant wartime contributions to systems engineering, and then took the audience on a grand tour of what he called "the postwar flowering of industrial systems synthesis". Editor Vannah had an intriguing system for classifying this postwar control fauna. He did it by grouping and referring to the mathematical tools that were used. Hence some systems developments were defined as offshoots of the classical method of employing differential equations; others involved operational methods such as Fourier or Laplace transforms; still others stemmed from the use of weighting functions; and a significant group were classified as products of new graphical techniques. Could be that Bill has been reading CONTROL ENGINEERING.

ASME Focuses on Valves

On Monday, Nov. 14, while Chicago's Exposition of Power and Mechanical Engineering holds forth at the Coliseum, the Instruments and Regulator Division of ASME will conduct a three-session symposium on the design, application, and hydrodynamics of automatic control valves. The morning design session will include papers on terminology, materials limitations, plug design, and evaluation of mechanical characteristics. In the afternoon two papers will deal with test and dynamic evaluation of valve and valve operators and the effect of adjacent piping on characteristics. This session will conclude with an exposition by Prof. Lowen Shearer of MIT on "Use of Non-linear Valve Characteristics in the Control of a Simple Blending Process". The symposium will end with a panel discus-

PLUG IT IN

Airpax Series 300 choppers are available in three mounting styles. The popular plug-in style, Type 300, fits a 7-pin miniature tube socket. It can be locked in place by a tube shield.

BOLT IT DOWN

For permanent mounting, Airpax supplies you with Type 303. The Series 300 chopper withstands shock and vibration, commending it to such rigid mounting.

OR STRAP IT ON

Or, for mounting parallel to a chassis, Type 302 is available. These choppers, rated for 2,000 hours life, can be soldered advantageously into many equipments.

THIS RUGGED LONG-LIFE CHOPPER CAN TAKE IT!

Airpax Series 300 choppers operate at 400 CPS. The SPDT contacts are rated for 2 MA at 100 V MAX.

For complete specifications write to

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DESIGNERS PRODUCTS COMPANY ENGINEERS
MIDDLE RIVER BALTIMORE 20, MD.

IT'S NOT WHAT YOU LOOK AT...

IT'S WHAT YOU SEE!

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FASTAX

A guided missile speeds skyward on its destructive flight. Minutes later it hits its target. What happened the moment it exploded ... one thousandth of a second later ... two thousandths of a second later? The human eye can't tell. The action is too fast ... but not too fast for FASTAX. With FASTAX, *the world's most versatile high-speed motion picture cameras*, action is stopped "cold" with pictures taken as high as 16,000 per second. Later these same pictures are projected and studied in detail.

WRITE for more detailed information on how FASTAX is *the engineer's most modern tool* ... how it can save your company time and money.

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WOLLENSAK OPTICAL COMPANY
ROCHESTER 21, N. Y.

sion which IRD subcommittee chairman C. R. Otto says ". . . can be of service to the larger groups of practicing instrument engineers who must have felt the need to consolidate their problems and discuss their ideas and experiences with other application and design engineers."

The Power Show, which will fill the exhibit space of the Chicago Coliseum from Nov. 14-18, will back up the symposium with several new products in the valve field. For example, one valve maker will unveil its "isoforce" actuator—one having equal force throughout its stroke. Valves will be only one phase of control hardware shown. There also will be a special Atomic Power Section.

Twilight Control Engineering

If you live in the New York area and would like to sharpen your knowledge of computer theory, pulse techniques, transistors, information theory, and systems analysis, try Columbia University. The School of Engineering on Broadway and 117th Street will offer six evening courses—three each semester—on these and allied subjects during the forthcoming academic year. To be eligible you must have a bachelor's degree in engineering or science and $50 for tuition for each course. The courses meet once a week at 7:10 pm sharp. More than one may be taken in a single semester. Each offers two points credit and if you complete all you become eligible for a graduate program leading to a Master's in Electrical Engineering.

If the education-bent engineer can't reach Morningside Heights, perhaps he can make it to the foot of Manhattan to take in one or more of a splendid series of study-groups sponsored this fall by AIEE. For example, a series of twelve lectures will start Oct. 5 on the principles and engineering applications of atomic energy. These will be held Wednesday at 6:30 pm in Room 240 of the Ebasco Building at 2 Rector Street. And on Tuesday, starting Sept. 27 at 6:30 pm, the engineer can bone up on transitor theory and applications in another series of twelve lectures in the spacious Western Union Auditorium at 60 Hudson Street. Registration fees for these downtown sessions are $15 per course to members of AIEE, ASME, ASCE, and NYSSPE, and $25 to all others. For all details write to L. E. Gray, c/o Ebasco Services, Inc., 2 Rector Street, New York 6, New York.

Doubling Univac's Speed!

The famous Remington Rand Univac® has widened even further its lead over other electronic business computing systems. Univac is still the *only* completely self-checked system...the only one which can read, write, and compute simultaneously without extra equipment. And now, the Univac II adds to these superior features the speed of a magnetic-core memory.

The Remington Rand magnetic-core memory is more than a laboratory promise. It has been in actual customer use for over a year, passing all tests with flying colors in the first commercially available electronic computer to use core storage suecessfully.

The capacity of the internal memory of Univac has also been doubled, giving instantaneous access to 24,000 numeric characters. (If needed, this can be increased to 120,000 characters.)

Univac's external memory—magnetic tape—now has greater capacity too, increasing input and output to 20,000 characters per second...the equivalent of reading or writing every character on this page more than 1,000 times a minute.

These new Univac developments can be incorporated into any existing installation to double its speed and to increase its economy still further.

ELECTRONIC COMPUTER DEPARTMENT **Remington Rand** ROOM 2039 315 FOURTH AVE., NEW YORK 10, N. Y.
DIVISION OF SPERRY RAND CORPORATION

ABC...and the Reader

BACK IN 1914—forty-one years ago—a group of advertisers, advertising agencies and publishers joined in a project that has come to mean a great deal to the millions who, like you, read business magazines. The project, initiated at a time when circulation claims were rarely verified, was intended to achieve and maintain higher standards of integrity in publishing and advertising practice by providing means to audit paid circulation. Out of that effort came an organization known as the Audit Bureau of Circulations, a voluntary, non-profit, cooperative association, known for short as ABC. Its symbol appears at the head of this page.

We are proud that McGraw-Hill publications were among the founders and charter members of the Audit Bureau of Circulations.

Today the Bureau numbers 3,670 members. These include advertisers, agencies, and publishers of newspapers, farm papers, general magazines and business journals such as this one. These publisher members hold their memberships and their right to display the ABC symbol in their publications only so long as they live up to the circulation standards that are established through the Bureau.

It is one thing to set up high standards; it is another to see that those standards are maintained. This latter and all-important function is performed by a staff of auditors maintained by ABC to check periodically on the circulation practices of the publisher members. When a business magazine, such as this one, joins the Bureau it agrees that the ABC auditors shall have "the right of access to all books and records." Their inspection may dig into the files of original subscription orders, payments from subscribers, paper purchases, postal receipts, arrears of payments, editorial expenses and many other significant items. Sometimes the auditors go behind the records and seek verification of purchase and payment from subscribers themselves.

The information thus obtained and certified by the Bureau then becomes available to the public and constitutes an authoritative report on the publication's circulation practices.

The advertisers and agencies benefit directly from the ABC because it provides a generally recognized factual yardstick by which the circulations of member publications can be measured and appraised. Every paragraph in an ABC report on a business publication gives the advertisers data that help them make intelligent use of the publication as an advertising medium.

But the ABC renders a service of vital concern to the *reader* as well. The Bureau audits paid circulation only, and it is through this payment, whether by subscription or newsstand purchase, that the reader keeps the editorial policy of a publication responsive to his needs. His decision to buy or not to buy records his judgment on each publication, and the ABC-audited and certified circulation reports make the sum of these judgments known to all concerned.

So the editors of ABC publications must constantly keep their editorial services up to the mark if they are to survive a competition in which the reader's right to buy or not to buy is paramount. Each paid magazine or newspaper will prosper or fail as it wins or loses the voluntary patronage of thousands or millions of readers. And—the ABC is scorekeeper in this vital contest.

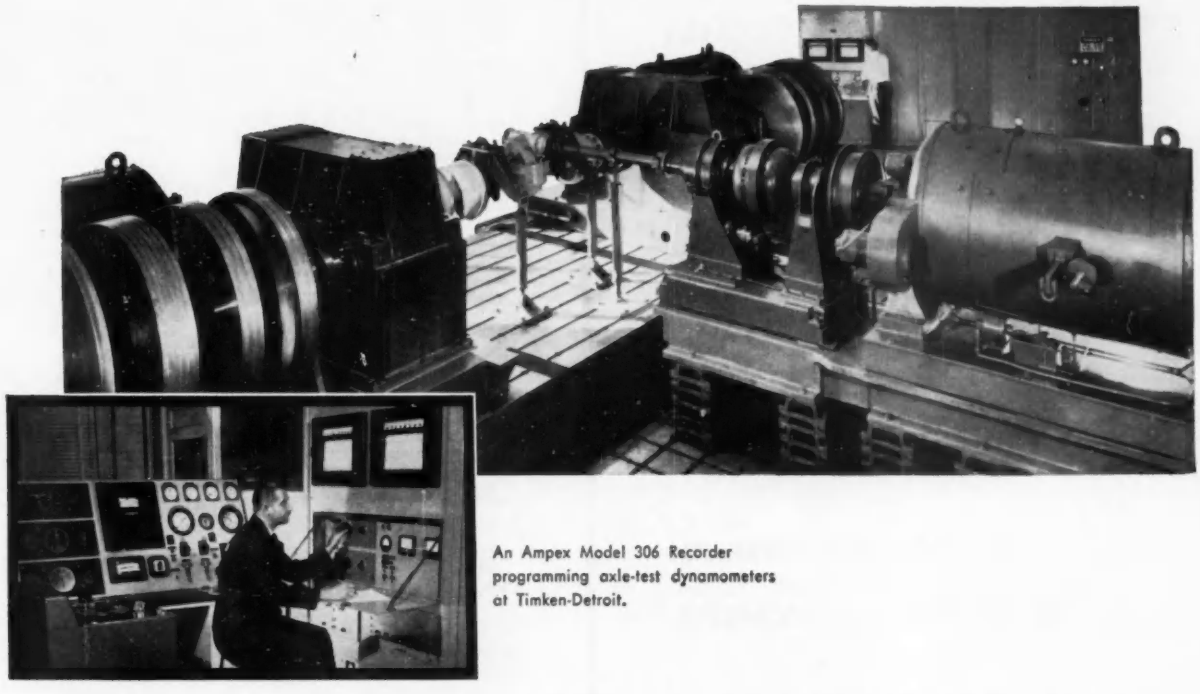
Thus the publisher who submits his publication to the supervision and discipline of ABC affirms in the strongest possible manner his recognition that his primary obligation is to his readers and that he owes the standing of his publication to a voluntary demand by those readers.

All this is what makes the ABC brand on a publication so important to its readers. That respected symbol, testifying to the advertising value of the publication, serves also as a constant reminder to all concerned that the reader's willingness to pay for an ABC publication is the basic reason why it stays in business.

McGraw-Hill Publishing Company, Inc.

MAGNETIC TAPE RECORDING

helps ***Road-Test*** *Timken Truck Axles*



An Ampex Model 306 Recorder programming axle-test dynamometers at Timken-Detroit.

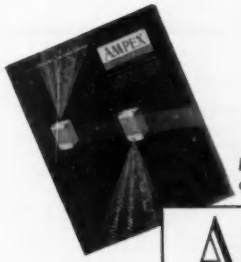
Magnetic tape recordings are now being used to duplicate rugged road-tests at the Timken-Detroit Axle Division of the Rockwell Spring and Axle Company, Detroit, Michigan. A four hour tape cycle is made of actual road surface and driving conditions . . . then played back through torque and speed dynamometers — repeatedly — until a test axle breaks down.
Result: more realistic and efficient testing — better axles for today's trucks, buses and trailers.

WHY TIMKEN CHOSE AMPEX

Timken engineers required a recording and playback medium that could give near-perfect reproduction of the original road test phenomena . . . and would playback indefinitely without introducing errors through wear and speed irregularities. They found that the Ampex F-M recorder best met these exacting requirements. Its extreme stability of tape motion, precise timing and consistent accuracy produced laboratory "road-test" results within 1% of actual conditions.

LET AMPEX STUDY YOUR REQUIREMENTS

Ampex manufactures the most complete line of magnetic recorders for complex and sensitive automation, communication and data-handling systems. Why not let Ampex application engineers determine what magnetic tape recording can do for you?



For further information, *send for our 16-page illustrated bulletin, "Data Recording, Machine Control and Process Regulation." Contact your nearest Ampex representative or write to Dept.* HH-1897

AMPEX CORPORATION

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5

Speedomax® X-Y Recorders

● Plotting X as a function of Y? Then one of these 5 types of Speedomax X-Y Recorders will answer your data plotting needs . . . will relieve you of time-consuming point-by-point plotting. You may require: a standard instrument for routine research and testing; a special recorder for low level emf, pH, load or other measurements; an X_1-X_2-Y Recorder for plotting two variables against another variable; a X-Y recorder that readily converts into an X-Time recorder for all 'round laboratory use; or a Polar Recorder that plots a function against angular displacement.

The listed specifications may help you determine which X-Y recorder meets your specific requirements.

1. STANDARD X-Y RECORDER

MEASURING CIRCUITS—D-C potentiometer for both X and Y axis.

RANGE SPAN—10 mv d-c on both X and Y axis. Circuits are modified for convenient field choice of zero left or zero center on X axis, zero bottom or zero center on Y axis.

BALANCING SPEEDS—1 second on X axis, 4 seconds on Y axis.

OPERATING AIDS—Chart tear-off device and solenoid-operated pen-lifter.

2. SPECIALIZED X-Y RECORDERS

MEASURING CIRCUITS—Either d-c potentiometer or Wheatstone bridge for X axis, for Y axis, or for both.

RECORD—Single-point curve drawing or multiple-point printing (up to 24 points) on X axis.

RANGES—X axis: 100 μv min., 1000 mv max.
Y axis: 1 mv min., 1000 mv max.
Additional ranges are available by using volt boxes, pre-amplifiers or high-impedance high-gain recorder amplifiers. Consult L&N Field Engineers about applications.

BALANCING SPEEDS—3, 2, or 1 second on X axis; 4 seconds on Y axis.

3. X_1-X_2-Y RECORDERS

MEASURING CIRCUITS—3 separate measuring and balancing systems for operating the X_1 and X_2 pens across the chart and the Y (or vertical) chart movement.

RANGES—Consult your L&N Field Engineer.

BALANCING SPEEDS—3, 2, or 1 second for X_1 and X_2 functions; 4 seconds for 10″ of chart motion on Y axis.

4. AN X-Y AND X-TIME RECORDER

A kit of parts is available for field conversion of a standard or specialized X-Y recorder into a conventional X-Time instrument. The Y axis chart drive is replaced by a synchronous motor chart drive with chart speeds ranging from 2″ to 3600″ per hour. Plugs facilitate connecting the Y function or Time function as needed.

5. SPEEDOMAX POLAR RECORDER

MEASURING CIRCUITS—D-C potentiometer, Wheatstone bridge or adjustable slidewire attenuator for r axis. θ axis or chart rotation (with zero at chart center) uses a synchro-servo system.

RANGES—emf measurements, as specified.
Null current measurements: 0 to 1, 0 to 2, or 0 to 5 μa. Power level measurements: 0 to 50 db.

BALANCING SPEEDS—r axis: 2 seconds for 5″ pen travel.
θ axis: 60 angular degrees per second with full chart rotation of 360 degrees.

For more complete information on this versatile line of Speedomax X-Y Recorders, ask our nearest Sales Office for Data Sheet E-ND46(1) or write to Leeds & Northrup Co., 4918 Stenton Ave., Philadelphia 44, Pa.

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Where Do Control Engineers Come From?

In last month's issue of CONTROL ENGINEERING an editorial theme, "The Roots of Automatic Processing", was sounded by Donald P. Campbell. In his provocative essay the brilliant scientist-engineer made the point that true automatic processes will only come when the engineer who designs them has his roots deep into the basic fundamentals of control—when he is alert to the powerful mathematical tools for dynamic analysis of existing systems, and for synthesis of new and better systems. The MIT professor called for more widespread and more rigorous academic training to turn out proper recruits for the new technology.

Whence the "optimized" control engineer?

Granted, "optimized" control engineers for future industry are still to come in quantity. But what about the present? Where does a trained control engineer come from now? And how rigorous is his schooling?

A detailed survey of the curricula of 67 accredited engineering colleges and universities by the Instrument Society of America's Education Committee provides some of the answers. The Committee found 1,014 courses that definitely smacked of instrumentation and control. Since all major schools were included in the survey, the Committee estimated that some two-thirds of the engineering students in this country have some opportunity to select courses in control technology. However, only two-thirds of these courses were open to undergraduates—the rest strictly for graduate students.

Definitely not "snap" courses, but . . .

And what about the rigor? The ISA Committee found that three-quarters of the courses ran only a single semester and that a third was simply lectures without lab work. Further, almost a full third was surveys and gave the student little more than description of hardware. Also noted: only a third of the courses required the use of differential equations or advanced calculus.

Where can the student specialize? Apparently electrical engineering courses offer today's best route to control technology. EE curricula provide almost all of the servomechanisms and feedback control instruction and have a monopoly on education in industrial electronic control and computer technology. In only two categories—process instrumentation and instrumental analy-

Los Angeles, Cal.

Fairchild announces the opening of a new plant in Los Angeles, California. The new plant will expand the manufacturing, sales and service activities of Fairchild's Potentiometer Division to provide equal facilities both in the East and the West. It will meet the growing need for its products by the expanding electronic and avionic industries on the West Coast. A complete line of potentiometers will be manufactured and the new plant will be staffed to provide complete engineering and fast delivery service.

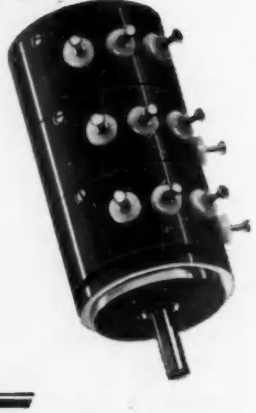
Hicksville, L.I., N.Y.

AVAILABILITY AND SERVICE

from L.I. to L.A.

The opening of Fairchild's new West Coast plant means that henceforward the name Fairchild will not only stand for the finest in precision potentiometers . . . it will mean faster delivery and better service, too. You will be able to get complete engineering service, quotations, order handling, delivery and repair from either plant, whichever is most convenient to you.

This is another example of how Fairchild can always give you the answers, no matter what factors govern your choice of precision potentiometers. Write Potentiometer Division, Fairchild Controls Corp., a subsidiary of Fairchild Camera and Instrument Corp., Dept. 140-66C1.



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FAIRCHILD
PRECISION POTENTIOMETERS

sis—are EE students overshadowed by those enrolled in chemistry and physics.

Of course, not all control engineers come, or will come, from special engineering classes. Only a handful—an estimated 2,000—academically specialized control engineers graduate each year. Filling the gap are the many design, production, or process engineers who have gravitated into the job opening (see this month's Control Personality, page 17, for a fine example).

How do they man the gap? A brief analysis of CONTROL ENGINEERING's 25,000 readers furnishes some surprising and reassuring answers.

The "volunteers" fill the gap—and well

First, where do these volunteer control engineers operate? They work in 65 different industrial classifications. But the numbers are weighty among advanced users of control such as aircraft makers and processing plants—there are over 5,500 in the former category, 7,500 in the latter. About 2,500 consulting and contracting engineers work in the field.

How qualified are the volunteers? A survey of a random 400 readers indicates that the average volunteer is well qualified indeed. He is a graduate engineer and his background may be either electrical or mechanical (only 15 per cent of the group specialized in other engineering disciplines). He has been out working about 15 years. His only "soft" point: the average man uses calculus easily in his work but only 101 out of the 400 can proceed with transforms or higher mathematics.

And here is the reassuring note. CONTROL ENGINEERING readers—both specialist and "volunteer"—appear to be uniform in one particular quality: an enthusiastic desire to learn. The proof is a constant feedback in letters and comments to articles which either (A) air a new technique, or (B) are primers. As long as our technology prompts this response, Donald Campbell's predictions have a fine chance of being realized.

built to do just one servo control job . . .

perfectly

An incremental synchro positioner before wiring to header and hermetic sealing. The synchro rotor is stepped in one or fifteen degree increments clockwise or counterclockwise depending upon which of four coils is momentarily energized by a d-c pulse. The synchro can be rotated any number of degrees or revolutions. The cylindrical member resets the synchro to electrical zero if a pulse is applied to the "reset" circuit.

Like all Transicoil servo assemblies, this incremental positioner "does the job right" because it was designed for a single application . . . by a company whose major function is to provide complete servo assemblies precisely engineered and manufactured to solve individual servo control problems.

Of course, if you merely want servo *components*, you'll find Transicoil's control motors, motor-gear train combinations, motor-gear train-generator combinations, and servo amplifiers built to the highest order of precision and accuracy. But it is in the "package" engineering of unique assemblies that Transicoil's experience and creative imagination offer the greatest value. And in most cases, these assemblies cost no more than the individual components would purchased separately.

That's why it pays to check your servo problems out with Transicoil first. Write outlining your problem, and ask for Transicoil's new gear-motor bulletin. You'll find it a mighty handy availability guide in designing for tight production schedules.

Transicoil

CORPORATION

Worcester • Montgomery County • Pennsylvania

Control
ENGINEERING
OCTOBER 1955

Meeting the Need for Electronic Control Standards

There is never a *right* time for erecting a complete structure of standards for instrument and control products. Either it is so late that divergent practices cannot be brought together, or it is so early that bad guesses may produce inadequate, over-rigid standards that hamper progress. But as the editors of CONTROL ENGINEERING advised on this page in the February issue, a sound framework of *guiding standards* should be built when a major product development is spotted and the need clearly defined.

A case in point exists today. Industrial electronic control elements are emerging to complement and, in some cases replace, complete pneumatic control systems. In line with this new approach, agreement is most urgently needed on signals transmitted from primary measuring converters to controllers and from controllers to the final elements that manipulate the controlling power and energy. The need is also great for similar standardization in those electronic control systems in which the measuring element connects directly to the controller and the controller itself handles the power supplied to the machine or operation under control. In such systems the machines used and the power required to drive them determine the signal requirements.

Because the signals of electronic control systems already on the market do not match, the ISA Recommended Practices Committee debated the question at its joint user-manufacturer meeting last November. For action the committee turned to the SAMA Recorder-Controller Section, the trade association of many of the manufacturers of industrial instruments and controls. The machinery has started to roll. Studies of standardization requirements and scope began in July.

It may be some time before SAMA, NEMA, ISA, AIEE's Feedback Control Committee, ASME's Instrument and Regulators Division, or IRE's Professional Group on Automatic Control sponsors an American Standards Association committee on the subject. But this sponsorship is the necessary giant step toward effective industry-wide electronic control standards. We urge all interested professional and trade associations to study the requirements, to establish liaison with one another, and to push for early results.

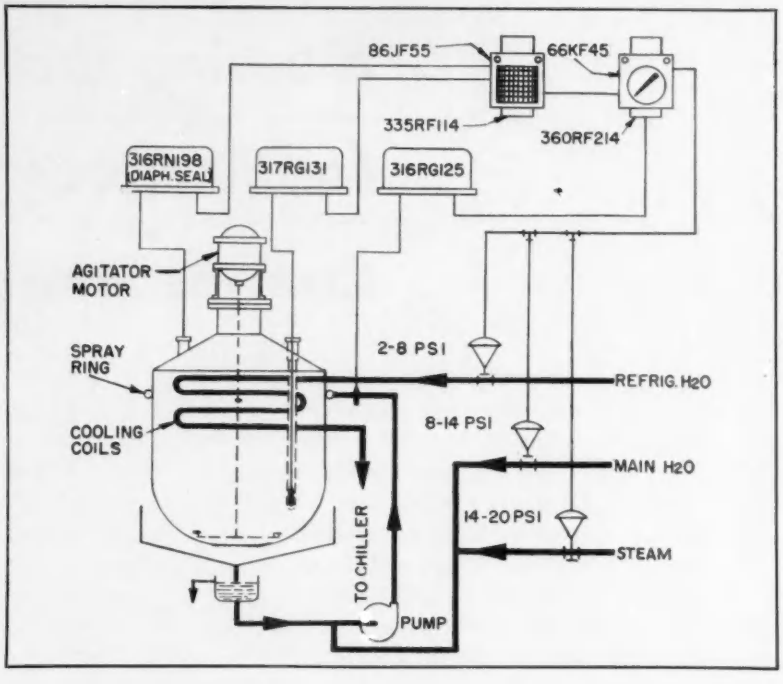
THE EDITORS

REACTOR CONTROL

One of a series of basic instrumentation recommendations for the unit operations

GEORGE E. HOWARD, Manager
Application Engineering Dept.

"Taylor pioneered in the development of control systems for chemical reactors. This recommendation is the result of many years of experience of our application engineers in handling problems inherent in this type of reactor. Data sheets on this and other reactor problems are available on request."



PROBLEM

To achieve maximum yield of specification product in the shortest possible time, with minimum cost. Optimum reaction rate is dependent on precise temperature control. This is difficult because of the lags inherent in the equipment. The principal lags are: the poor transfer of heat from product to the measuring element through a heavy protective well; and slow heat transfer into or out of the product through the vessel wall.

SOLUTION

The first lag problem is compensated for by the use of SPEED-ACT* (derivative) response in the measuring system of the TRANSAIRE* Temperature Transmitter. This permits rapid and accurate sensing of any temperature changes as the reaction proceeds.

Capitalizing on the dynamic accuracy of the TRANSAIRE Transmitter, the TRI-ACT* Controller, with its unique circuit arrangement, makes possible fast "come-up" without overshoot. Yet, it maintains the control point within extremely narrow limits regardless of process upsets. A vital contribution to this precision control is the cascade system which keeps spray-ring water temperature at the value required to accurately maintain product temperature, thus taking care of lag through the vessel wall.

The TRANSET* miniature receiver permits a continuous record of product temperature with the added convenience of auto-manual switching and remote set point change.

BENEFITS

1. Faster, safer "come-up" time.
2. Danger of wild reaction eliminated.
3. Maximum yield of specification product in shortest possible time.
4. Duplication of quality, batch after batch.
5. No loss of raw material due to over or under reaction.
6. Economical production through conservation of heating and cooling media.

* * *

Reaction problems that might well benefit from such a control system include those involved in the production of Polystyrene, Plastics, Synthetic Rubbers, Synthetic Resins, Antibiotics, Intermediates.

Send for Data Sheet No. 9 covering in greater detail the recommended instrumentation for this and other types of reactors. Watch this magazine for future Taylor advertisements dealing in a similar manner with other unit processes. In the meantime, don't forget that Taylor Field Engineers have had intensive training and many years of experience in solving all kinds of instrumentation problems. They are ready, willing and able to serve you. Taylor Instrument Companies, Rochester, N.Y.; Toronto, Canada.

*Trade Mark

Taylor Instruments **MEAN ACCURACY FIRST**

TWO WAYS TO GET FREQUENCY RESPONSE FROM TRANSIENT DATA—

For Those Who Analyze Occasionally:

A Graphical Approach

by A. R. TEASDALE, JR.
Temco Aircraft Co.

For Those Who Analyze Often:

An Analog Machine Approach

by J. B. REYNOLDS, JR.
E. I. du Pont de Nemours & Co.

SOME BACKGROUND COMMON TO THE TWO APPROACHES:

The frequency response techniques furnish a powerful tool for analyzing the stability and performance of feedback systems. The transfer function is the ratio of output signal to input signal, characterized as amplitude and phase shift plots at various frequencies in frequency response data. When system parameters are known the transfer function is represented by an equation and the frequency response determined mathematically. There are many cases, however, when physical systems have vague parameters and transfer functions of extreme complexity. A straight mathematical determination then is tedious.

Physical systems may be directly measured by frequency response, bypassing the mathematics. This eliminates one problem but creates others. The usual procedure is to apply a sinusoidal, constant-amplitude signal and measure the relative amplitude and phase shift of the output signal. For good results, these measurements are made frequency-by-frequency through the region of interest. But in practice it is not always so simple: system disturbances may upset the tests, product may spoil, and the special equipment for generating low-frequency sine wave inputs and for recording output signals may be too costly.

Another route to frequency response is to note the transient response of an impulse input to the system. The transient method is easier to initiate and record. And it contains all information necessary to determine the steady-state frequency response.

In the transient data approach, various order impulses can be imparted to the system. Some are easier to generate than others. And all create a disturbance. But this disturbance is short compared to the time involved in taking a frequency response run. Each order of impulse, applied individually to the same system, has its own response. Each impulse also has its own procedure for converting from transient to the equivalent frequency response. And the same frequency response is obtained for a given system, regardless of the type impulse generated.

Normally, a fairly rigorous mathematical treatment is used to bridge input impulse to output transient and specify the transfer function. But here are two articles that offer a quick and fairly uncomplicated way of carrying out the calculation. The first is a graphical approach: it applies graphical integration of transient data to systems where the actual transfer function is unknown, as well as to systems where previous calculations are to be verified. And it suggests that wide-range frequency tests—usually needed—can be eliminated.

The second article describes a special computing machine developed at du Pont to speed the frequent conversion from transient to frequency response. The computer plots amplitude and phase angle characteristics as a function of frequency directly from the transient record. And while the hardware appears to be expensive, its contribution to speed the accuracy should justify the outlay.

METHOD NO. 1

Get Frequency Response From Transient Data By Adding Vectors

A. R. TEASDALE, JR., Temco Aircraft Co.

The graphical procedure for converting to frequency response is an approximation method. As will be shown later, the mathematical relationship between transient and frequency responses involves complex integration. In the graphical method this is simply the addition of a group of vectors, the resultant vector indicating the amplitude and phase-shift at a particular frequency. Simple repetition of this procedure at different frequencies determines the frequency response of the system.

The mathematical analysis assumes the following characteristics of the system under consideration:

- The system is linear.
- The system transfer function, $G(s)$, has a denominator of order equal to or greater than the numerator.
- The system is at rest before the transient is applied.
- For a unit step-function applied to the input at $t=0$, the output, $h_o(t)$, approaches some constant value as t increases without limit.

The Laplace transform of the output, $C(s)$, is stated by

$$C(s) = G(s)R(s). \tag{1}$$

Impulses of order zero, one, and two are shown in Figure 1 with corresponding Laplace transform, $R(s)$, and system response, $h_n(t)$; $s=c+j\omega$ is the complex variable for the Laplace transform.

The electrical analogy for a double-phase lag network is shown in Figure 2; the transfer-function, determined mathematically, is:

$$G(s) = \frac{1}{(0.5s+1)(0.1s+1)} \tag{2}$$

Substituting $j\omega$ for s in Equation 2, the steady-state frequency response (amplitude and phase-shift plots) is shown in Figure 3. The transient outputs of several input functions are obtained by inverse Laplace transformation:

INPUT	TRANSFER FUNCTION	TRANSIENT
a) Unit-step		$h_o(t) = 1 + 0.25e^{-10t} - 1.25e^{-2t}$
b) Unit-impulse	$\dfrac{1}{(0.5s+1)(0.1s+1)}$	$h_1(t) = -2.5e^{-10t} + 2.5e^{-2t}$
c) Unit-doublet impulse		$h_2(t) = 25e^{-10t} - 5e^{-2t}$

Transient responses of the above known system have been chosen, correlating graphical and mathematical evaluations of the frequency response.

3 WAYS TO DERIVE:

I—FROM A UNIT STEP-FUNCTION

When a unit step-function is applied at $t=0$, $R(s)=1/s$ and $C(t)=h_o(t)$. The system relationship is stated as:

$$C(s) = G(s)R(s) = G(s)/s \tag{3}$$

The Laplace transform of the first derivative of the output with respect to time is given by:

$$C'(s) = sC(s) + h_o(t)|_{o+} \tag{4}$$

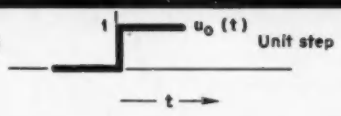
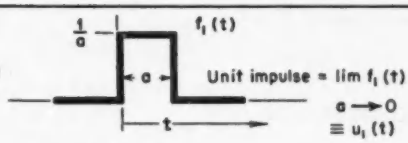
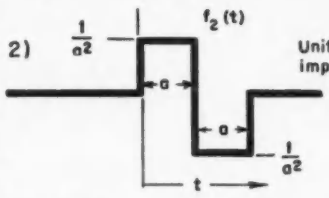
According to assumption (3) the last term of Equation 4 is zero. Therefore, the transfer function is $G(s)=C'(s)$ and the Laplace transform of the transfer function is

$$G(s) = \int_0^\infty h'_o(t)e^{-st}\,dt. \tag{5}$$

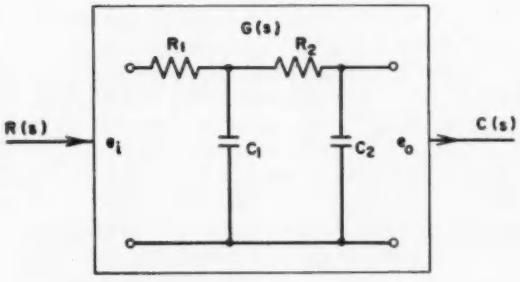
The first derivative, $h'_o(t)$, of $h_o(t)$ approaches zero as t becomes increasingly large (assumption 4.) The integral, therefore, converges for the real part of $s=c+j\omega$ taken as zero and substituting $j\omega$ for s in Equation 5,

$$G(j\omega) = \int_0^\infty h'_o(t)e^{-j\omega t}\,dt$$

$$= \int_0^\infty e^{-j\omega t}\,d[h_o(t)]. \tag{6}$$

IMPULSE ORDER	LAPLACE TRANSFORM	SYSTEM RESPONSE
0) 	1/s	$h_0(t)$
1) 	1	$h_1(t)$
2) 	S	$h_2(t)$
m) $\lim_{a\to 0} \frac{[1-e^{-ap}]^m}{a^m} 1$ where 1 = unit step function e^{-ap} = time delay operator p = time derivative operator, d/dt	s^{m-1}	$h_m(t)$

Input impulses initiate transient output. Order zero, one, and two impulses, as used in the text, are defined. Laplace transforms for these and other order inputs can be obtained from the generalized (m_{th}) order. FIG. 1



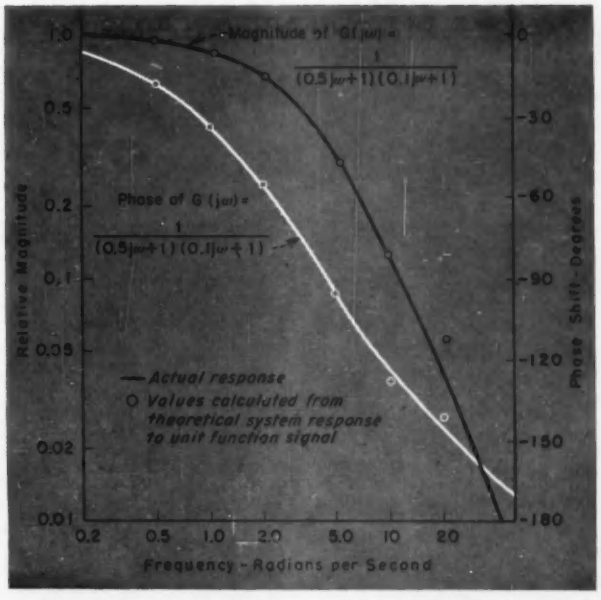
R_1 = 50,000 ohms C_1 = 5 microfarads

R_2 = 66,666 ohms C_2 = 3 microfarads

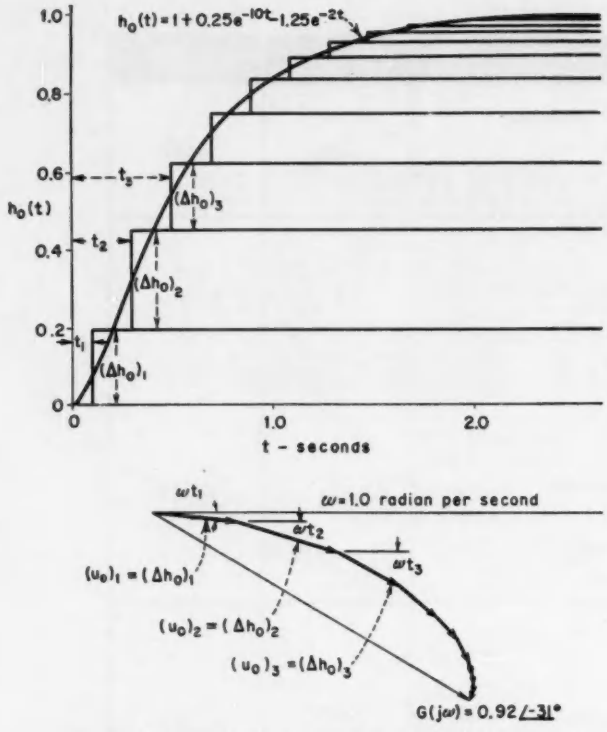
$$G(s) = \frac{e_o(s)}{e_i(s)} = \frac{1}{R_2R_1C_1C_2s^2 + (R_1C_1 + R_2C_2 + R_1C_2)s + 1}$$

$$= \frac{1}{(0.5s+1)(0.1s+1)}$$

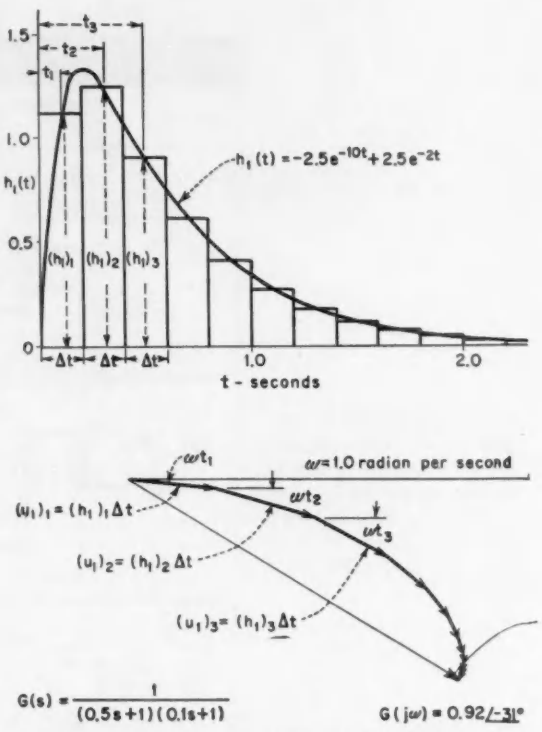
The double-phase lag network represents a simple transfer function. The ratio of output to input signals is G(s). This known function is used to compare the results of the graphical method with mathematical analysis. FIG. 2



Frequency response plots of the transfer function shown in FIG. 2. The amplitude and phase-shift curves are shown solid when $j\omega$ is substituted for s in the function. Circles represent points obtained by repetition of graphical operations on the transient record. FIG. 3



Transient record when zero-order (step-function) input is applied to the function in FIG. 2. Graphical summation at $\omega = 1$ per Equation 7a, gives the amplitude and phase-shift for the transfer function at that frequency. FIG. 4



Transient record when second-order (unit-doublet impulse) input is applied to the function in FIG. 2. Graphical summation per Equation 10a at $\omega = 1$ gives the amplitude and phase-shift at that frequency. FIG. 5

Equation 6 may be integrated numerically,

$$G(j\omega) \doteq \sum_{n=1}^{\infty} \Delta h_o(t_n) \angle -\omega t_n. \qquad (7)$$

The transient response, $h_o(t)$, of a unit step-function applied to $G(s) = \frac{1}{(0.5s+1)(0.1s+1)}$ is shown in Figure 4. Frequency response is obtained by graphing operations implied in Equation 7.

The sum of a series of step-functions approximates $h_o(t)$; the magnitude of the first step-function is $(\Delta h_o)_1$, delayed by a time, t_1; the magnitude of the second step-function is $(\Delta h_o)_2$, delayed by a time, t_2; etc. The phase of the output with respect to input for each component is $(-\omega t_n)$, where ω is the frequency in question and t_n is the time delay of the n^{th} step-function component. For convenience, equal times are taken after t_1.

Equation 7 states that the amplitude and phase-shift, at a given frequency, is the resultant vector of a group of individual vectors:

$$G(j\omega) \doteq \Delta h_o(t_1) \angle -\omega t_1 + \Delta h_o(t_2) \angle -\omega t_2 + \Delta h_o(t_3) \angle -\omega t_3 + \Delta h_o(t_4) \angle -\omega t_4 + \ldots + \Delta h_o(t_n) \angle -\omega t_n \qquad (7a)$$

Increments Δt of t are taken sufficiently small so $\Delta h_o(t_n)$ will be small compared with unity and $\omega \Delta t$ is small compared with one radian.

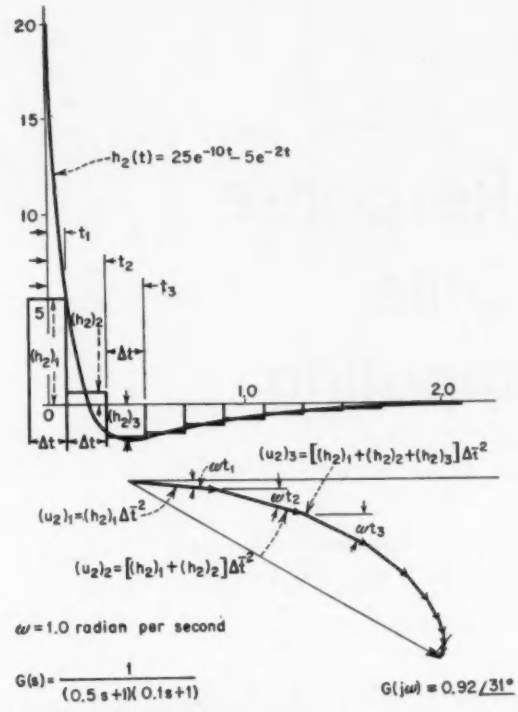
In Figure 4, $\Delta h_o(t_1) = 0.2$ and $t_1 = 0.1$ sec are scaled off, and at $\omega = 1$ the first component vector has a magnitude of 0.2 at an angle of minum 0.1 radian (−1 times 0.1). This is plotted, starting from the origin. The second vector is $0.26 \angle -0.3$; the third is $0.175 \angle -0.5$; etc. The individual vectors are connected, forming an open polygon. The resultant vector closes the polygon—the magnitude and angle of the resultant ($0.92 \angle -31$ deg) are the amplitude and phase-shift of the transfer function at $\omega = 1$.

The procedure is repeated at other frequencies to obtain their corresponding resultants. The magnitudes and phase-shifts, plotted at their corresponding frequencies, describe the frequency response characteristics of the transfer function, Figure 3.

The graphical method compares favorably with the mathematical calculations; accuracy is lost, as at $\omega = 20$, when the frequency response becomes a small fraction of the maximum response.

II—FROM A UNIT IMPULSE

The Laplace transform of the unit-impulse input is $R(s) = 1$, and the response to the input is



Transient record when second-order (unit-doublet impulse) is applied to function in Figure 2. Adding the vectors per Equation 12a results in the same response as in the first two cases. Here graphing is more involved. FIG. 6

$C(s)=h_1(t)$. The Laplace transform of the output becomes

$$C(s) = G(s)R(s) = G(s) \tag{8}$$

and the transfer function is

$$G(s) = \int_0^\infty h_1(t)e^{-st}\,dt. \tag{9}$$

The assumptions hold and $j\omega$ is substituted for s, so

$$G(j\omega) = \int_0^\infty h_1(t)e^{-j\omega t}\,dt \doteq \sum_{n=1}^{\infty} h_1(t)(\Delta t_n) \angle -\omega t_n. \tag{10}$$

The transient response, $h_1(t)$, of a unit-impulse applied to $G(s) = \dfrac{1}{(0.5s+1)(0.1s+1)}$ is shown in Figure 5. Frequency response is obtained by performing graphically the operations implied in Equation 10. The sum of a series of unit-impulses approximates $h_1(t)$. The magnitude of the first unit-impulse is $(h_1)_1(\Delta t_1)$ and the angle is $(-\omega t_1)$; the second is $(h_1)_2(\Delta t_2)$ at an angle $(-\omega t_2)$; etc., where ω is the frequency in question.

Equation 10 states that the amplitude and phase-shift at a given frequency is the resultant vector of a series of vectors:

$$\begin{aligned} G(j\omega) = {} & h_1(t_1)\,\Delta t_1 \angle -\omega t_1 + h_1(t_2)\,\Delta t_2 \angle -\omega t_2 \\ & + h_1(t_3)\,\Delta t_3 \angle -\omega t_3 + h_1(t_4)\,\Delta t_4 \angle -\omega t_4 \\ & + \ldots + h_1(t_n)\,\Delta t_n \angle -\omega t_n \end{aligned} \tag{10a}$$

The individual vectors are plotted, Figure 5. The amplitude and phase-shift at $\omega=1$ again results as $0.92\angle -31$ deg; this was to be expected because it is the response at the same frequency for the same transfer function. The procedure, repeated at various frequencies, brings the graphical results of the frequency response, Figure 3.

III—FROM A UNIT-DOUBLET IMPULSE

The Laplace transform of the unit-doublet impulse input is $R(s)=s$, and the response to the input is $C(t)=h_2(t)$. The Laplace transform of the output becomes $C(s)=sG(s)$. The assumptions hold; $C(s)/s$ is the Laplace transform of the integral of the output with respect to time, $h_2^{-1}(t)$.

$$G(j\omega) = \int_0^\infty h_2^{-1}(t)e^{-j\omega t}\,dt. \tag{11}$$

If equal increments are taken for Δt, the numerical compex integration for $G(j\omega)$ is given by

$$G(j\omega) \doteq \sum_{n=1}^{\infty}\left[\sum_{q=1}^{n} h_2(t_q)\right](\Delta t)^2 \angle -\omega t_n \tag{12}$$

In manner corresponding to the first two cases, the transient response, $h_2(t)$, is integrated graphically in Figure 6, using Equation 12. This equation may be restated as:

$$\begin{aligned} G(j\omega) = {} & (h_2)_1(\Delta t)^2 \angle -\omega t_1 + [(h_2)_1 + (h_2)_2](\Delta t)^2 \angle -\omega t_2 \\ & + [(h_2)_1 + (h_2)_2 + (h_2)_3](\Delta t)^2 \angle -\omega t_3 + \ldots \\ & \ldots + \left[\sum_{q=1}^{n} h_2(t_q)\right](\Delta t)^2 \angle -\omega t_n. \end{aligned} \tag{12a}$$

For this case the graphical procedure is more complicated than the first two, but the resultant vector for the same transfer function, at $\omega=1$, is again $0.92\angle -31$ deg.

The method given above for determining the steady-state frequency response from the transient response to a unit-step function, unit impulse, and unit-doublet impulse may be extended to include higher order impulses. In each case, the output transient may be visualized as a series of same order impulses.

Any order impulse, used as a test signal, provides similar results for a particular system. From a practical view, unit-step and unit-impulse functions are more convenient to generate. And graphical determination of the transfer function from the transient response is probably easier and more accurate with these two signals.

REFERENCE

SYSTEM FREQUENCY RESPONSE DERIVED FROM TRANSIENT RESPONSE, A. R. Teasdale, Thesis for MSEE degree, 1950, University of Texas, Austin, Texas.

METHOD NO. 2

Get Frequency Response From Transient Data By Machine Computing

J. B. REYNOLDS, JR., Engineering Research Lab., E. I. du Pont de Nemours & Co.

Consider the transfer function of a chemical process. Process control variables may occur as flow-rate changes, addition of heat, or pressure surges, while the output response may be in terms of viscosity, product quality, composition, pressure, or liquid level. Processes become so complex that equations representing the system may defy formulation. And long time-constants (in the order of hours) may prohibit frequency response analysis of the system in operation. It then becomes necessary to impart a transient disturbance to the system, record the time-domain output, and convert the output to the frequency domain for systems analysis.

To facilitate accurate computation and solve tedious calculations in minimum process tie-up time, the Engineering Research Laboratory at du Pont has developed a special purpose analog machine that converts transient data to frequency response. The method involves:

- Recording output transient on magnetic tape
- Feeding a closed-loop portion of tape containing the signal first into a modulator and then to a rotating two-phase resolver that separates the signal into sine and cosine components
- Integrating each component
- Producing separate dc voltages proportional to amplitude and phase, and
- Recording the output signals versus frequency

THE MATHEMATICS

The mathematical operations performed by the automatic analyzer derive from the relationship between the input disturbance to the process and its transient output. This relationship is given by the convolution integral:

$$P_o(t) = \int_{-\infty}^{t} P_i(\theta)\, Y(t-\theta)\, d\theta \qquad (1)$$

$Y(t\text{-}\theta)$ is called the weighting function. If $P(\theta)$, the input disturbance, is stipulated as a unit-impulse function, the output becomes identical to the weighting function. And the Fourier transform of the weighting function describes the transfer function of the process:

$$Y(j\omega) = \int_{-\infty}^{\infty} Y(t)e^{-j\omega t}\, dt = F[Y(t)] \qquad (2)$$

Since approximating a unit-impulse function for many physical systems may not be feasible, these general relations pertain[2]:

$$Y(j\omega) = \frac{F[P_o(t)]}{F[P_i(t)]} = \frac{P_o(j\omega)}{P_i(j\omega)} = \frac{R_o + jI_o(\omega)}{R_i + jI_i(\omega)} \qquad (3)$$

Equation 3 simply means that at any frequency, ω, real and imaginary components specify the magnitude and phase angle for an integrated transient signal. For instance, the characteristics of the output are:

$$|\, P_o(\omega)\,| = [R_o^2(\omega) + I_o^2(\omega)]^{1/2} \qquad (4a)$$

and

$$\phi_o(\omega) = \arctan \frac{I_o(\omega)}{R_o(\omega)} \qquad (4b)$$

By rules of complex algebra, Equation 3 combines into one equation:

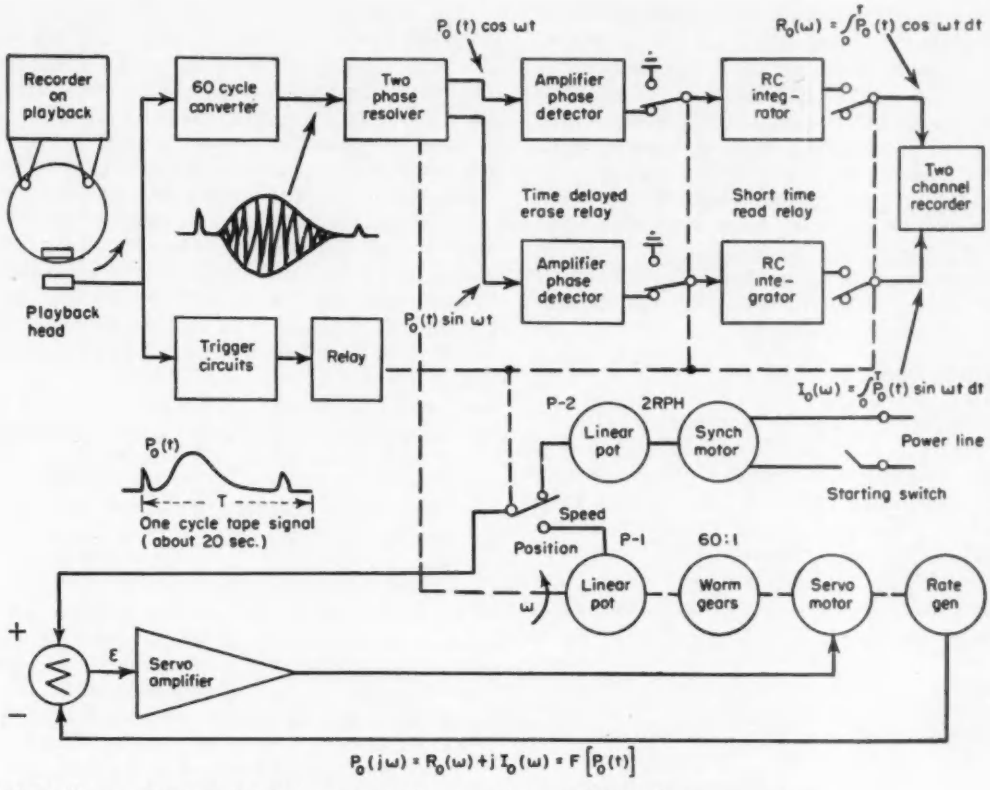
$$Y(j\omega) = R + jI(\omega), \qquad (5)$$

where

$$|\, Y(j\omega)\,| = |\, P_o(\omega)\,|_{db} - |\, P_i(\omega)\,|_{db} \qquad (6a)$$

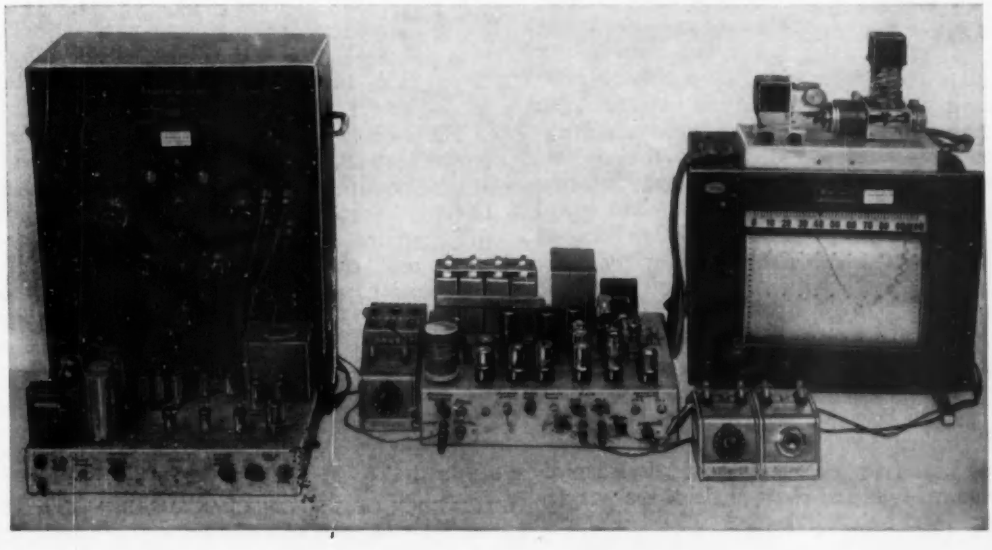
$$\text{and } \phi(\omega) = \phi_o(\omega) - \phi_i(\omega) \qquad (6b)$$

Although equipment can be designed to provide the results of Equations 6a and 6b, practical considerations limit this equipment to plotting frequency response of transient output. The latest



Block diagram of original (Model I) computer for converting recorded transient response to the frequency domain. Equipment gives output signals that are real and imaginary components of the amplitude and phase angle. Simple mathematical treatment (Equations 4a and 4b) yields magnitude and phase shift as a function of frequency. FIG. 1

Breadboard arrangement displays original version of transient analyzer. Two-pen recorder is on right, showing a typical record. FIG. 2



computer designed to handle this calculation automatically plots $P_o(\omega)$ and $\phi_o(\omega)$ as in Equations 4a and 4b. In many cases, the input disturbance is a familiar type of impulse and its frequency response characteristics are determined easily by non-machine methods. For instance, the frequency domain function of the unit-impulse input is $1+j0$ (unity magnitude and zero phase angle for all ω). As noted previously, output frequency response for this input is identical to the system transfer function. Once the output frequency response has been obtained, it is a relatively simple matter to determine the transfer function by Equations 6a and 6b.

THE MACHINE

The computer employs conventional circuit techniques. Figure 1 is the block diagram of Model I computer. This machine represents du Pont's first successful engineering approach to automatic transient analysis. Although the computer functions quite well, it has one deficiency: it does not plot $P_o(\omega)$ and $\phi_o(\omega)$, but rather $R_o(\omega)$ and $I_o(\omega)$. Determining $P_o(\omega)$ and $\phi_o(\omega)$ requires extensive additional computation, as indicated in Equations 4a and 4b.

Incidentally, Model II computer, currently under construction by Feedback Controls, Inc., incorporates additional circuitry (Figure 4) to overcome this drawback and plot $P_o(\omega)$ and $\phi_o(\omega)$ directly.

Let's get back to Model I (Figure 2). The suppressed-carrier modulated transient signal, $P_o(t)$, excites the stator of the resolver. Space quadrature relationship of the two (rotating) rotors multiplies $P_o(t)$ by the instantaneous angle, ωt, resulting in $P_o(t)\cos \omega t$ and $P_o(t)\sin \omega t$. These outputs are amplified, phase-detected, and impressed onto individual 400-sec time-constant RC integrators. The integrator outputs are, therefore, proportional to $R_o(\omega)$ and $I_o(\omega)$. At the end of each integrating period triggered relays transfer the voltages to the recorder chart as functions of frequency ω, where the integration occurred.

Point by point scanning over a frequency ratio of 1,000 to 1 (three decades) is automatically obtained by gearing a synchronous motor to a potentiometer; this, in turn, linearly increases the speed of a servomotor control system connected to the resolver rotor. While resolver frequency, ω, slowly increases, the closed-loop tape containing the transient record repeatedly feeds through the playback head at rate of one complete sweep about every 20 sec. Thus the transient signal generates new values of amplitude and phase angle for each increment of resolver frequency. Although the frequency does change slightly during the integrating period (about one per cent of the total frequency band) it may be considered constant because errors are averaged out. The record chart's horizontal coordinate represents the steady-state frequency (rad/sec), and the vertical coordinate both amplitude and phase angle of the transfer function. Model I plots 100 points in 30 min.

Two trigger pulses, inserted on the tape before and after the transient record, accomplish phase coherence and readout. Readout occurs for ½ sec during the non-integrating interval, followed by time-delay relay action to short the condensers and erase the voltages. The first pulse trips the resolver drive from position-servo to speed-servo action and at the same time unshorts the RC integrators. After integration a second pulse triggers a set of relays to transfer the resolver drive from speed to position control, forcing the resolver to the same angular coordinate at the end of each cycle. Periodic transfer to position control assures that playback speed and instantaneous angle of the rotor at the start of each sweep are properly synchronized. If this phase coherence were not maintained at the start, that is, if $P_o(t)\cos \omega t$ were not at maximum and $P_o(t)\sin \omega t$ were not at zero, a phase angle error would be introduced as a non-integer function of the number of revolutions. This would appear as an incorrect voltage at readout.

Typical information received from the computer is shown in Figure 3. It represents the Fourier transform coefficient of the response of a Foxboro Model 58 pneumatic controller with 500 per cent proportional band and one-minute rate setting. The reduction of this data to a plot of amplitude and phase versus frequency yields striking corroboration of data obtained using a pneumatic sinusoidal signal generator and a strain gage pickup at the output.

Model II computer has been so designed that the output amplitude and phase angle can be read directly. Because an error develops with the RC integrator during the start of the integrating interval, true definite electromechanical integrators will be used. These eliminate the two channels of amplification, phase detection, and RC integration. Two additional servos and another two-phase resolver (Figure 4) represent the major improvement. The servomechanism (on bottom, left) nulls the feedback signal from one rotor winding, thus establishing $\phi_o(\omega)$ as a shaft position. The other servo (bottom right) drives a potentiometer proportional to $P_o(\omega)$, thus completing the desired computation. Voltages derived from the potentiometer positions will be impressed on the recorder during readout.

The measurement and computing technique presented here affords a rapid solution to the problem of time domain to frequency domain transformation. Different magnetic tape speeds enable the computer to determine the transfer functions of processes whose time constants range from a few milliseconds to several hours. It can be applied to electromechanical servo systems or to full-scale plant processes.

Sincere appreciation is expressed for assistance extended by R. L. McCarthy and R. P. Bigliano.

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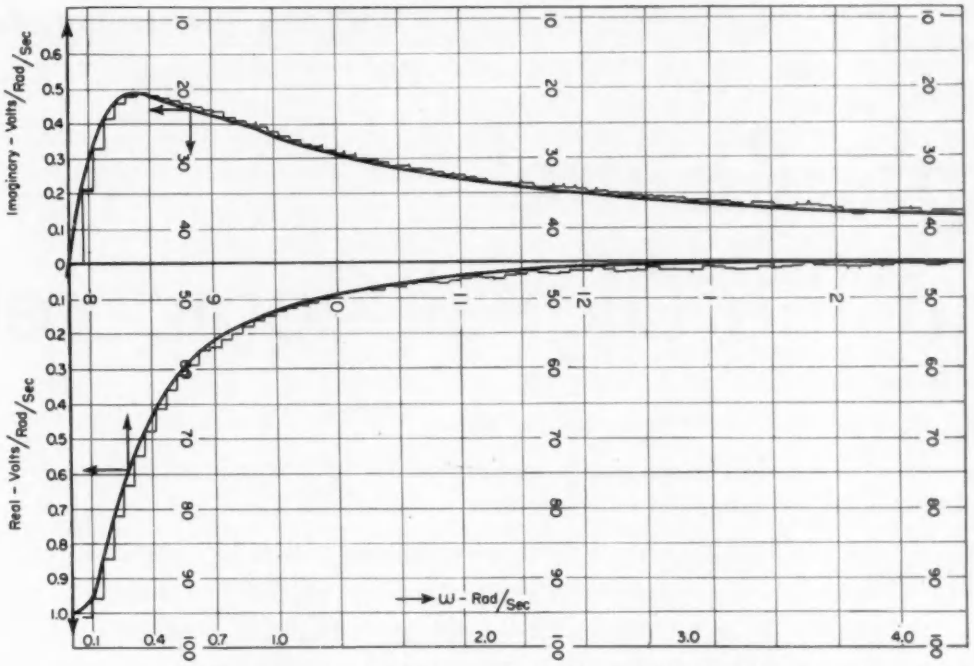
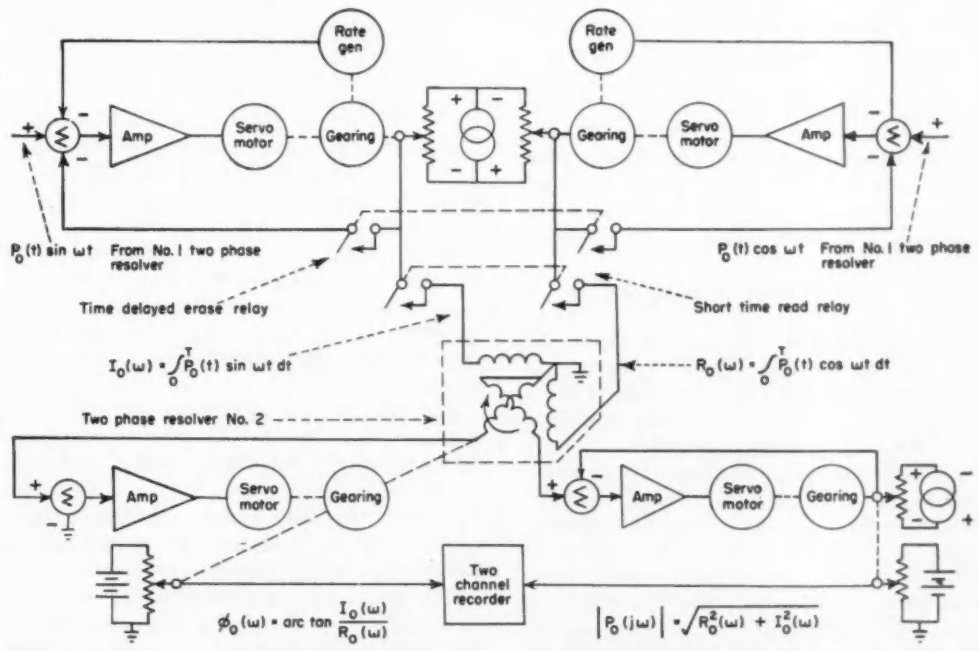
1. *INFORMATION THEORY*, S. Goldman, pp. 223-224, Prentice-Hall., 1953.

2. *THEORY OF SERVOMECHANISMS*, H. M. James, M. B. Nichols, and R. S. Phillips, p. 48, McGraw-Hill Book Co., 1947.



Output curves recorded from transient response of disturbance input to Foxboro Model 58 pneumatic controller. Data reduced to amplitude and phase angle tracked well with information obtained by sinusoidal input method of frequency response. FIG. 3

LABORATORY MODEL II-ADDITIONAL COMPUTING FUNCTIONS



Additional equipment to be used in Model II computer. It includes electomechanical integrators and two servos fed from a two-phase resolver. The servos null the component signals, giving voltage readings directly proportional to amplitude and phase angle, thus eliminating additional manual computations. FIG. 4

Flight Control and the Digital Computer

To help the engineer understand and appreciate his tools CONTROL ENGINEERING occasionally publishes an Application Study on a pioneering technique at work. This is such an article. It tells the story of the first successful airborne digital computer for automatic navigation and flight control.

EUGENE M. GRABBE, The Ramo-Wooldridge Corp.

The "Digitac" project began at Hughes Aircraft Co. in 1948 as a study contract for the Armament Laboratories, Wright Air Development Center. It continued through the development, construction, and flight stages. "Digitac" stands for Digital Tactical Automatic Control, a name coined for an automatic aircraft navigation and weapons control system. It was executed by a small team of young engineers who were asked to develop a high precision system based on hyperbolic position determination.

PRIOR NAVIGATIONAL SYSTEMS

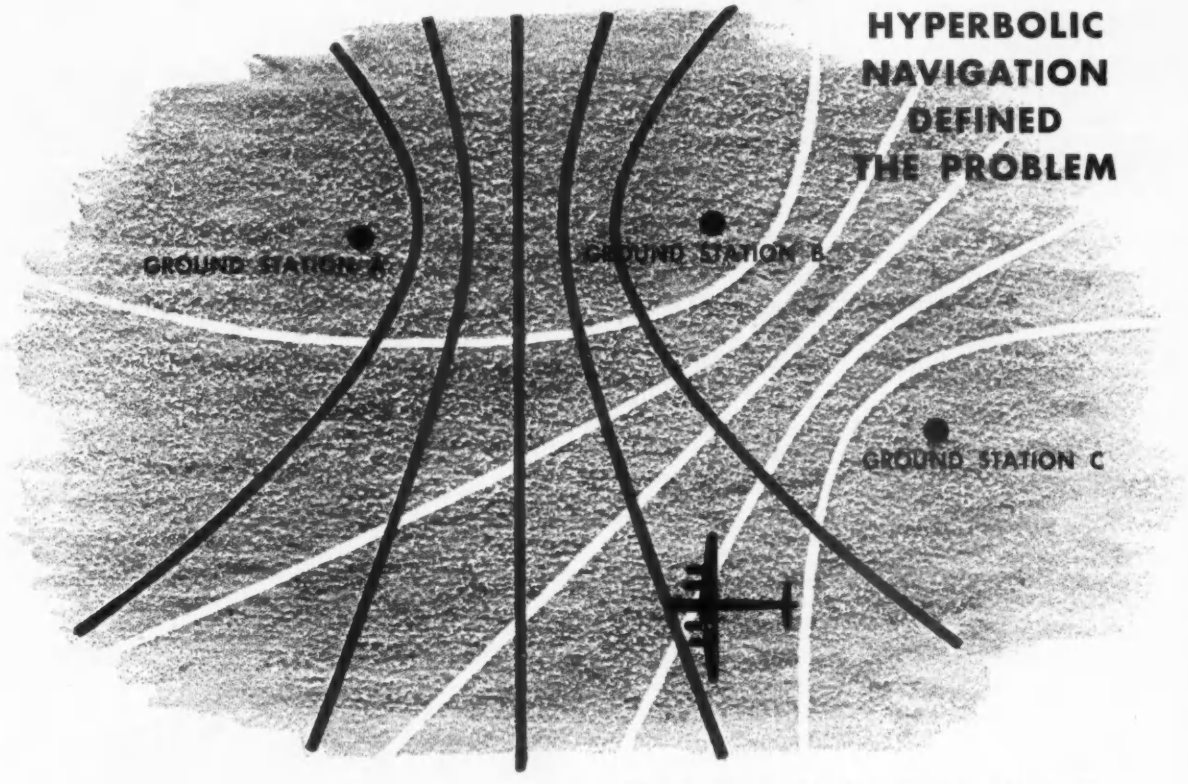
Hyperbolic baseline guidance systems like Loran have been used since World War II as navigation aids for aircraft and naval vessels. An operator notes the relative position of pulses on a scope and then finds his position by reference to charts. In any hyperbolic system, two pairs of ground-based transmitter stations are necessary to establish the coordinate system. One of the stations is usually common to both pairs so that three stations are sufficient. One (master) station alternately sends pulses to each of the other two (slaves) which relay the pulses to the aircraft. Measurements of the differences between the time of arrival of pulses from the master station and the slave stations define two hyperbolic lines of position so that a position fix can be made at their intersection. (See Figure 1).

The airborne Digitac system had to operate at line of sight on pulses transmitted from the ground stations. A hyperbolic navigation system has an unlimited traffic handling capacity and the aircraft maintains radio silence. In the study the Air Force encouraged the engineers to consider any novel approaches that might lead to an advanced system.

A quick initial error analysis of the system indicated that new developments would be required to meet the specifications in practically every part of the system—a common situation in military systems work. A hyperbolic system has an inherent geometric error due to coordinate divergence which increases with range from the ground stations. Hence, for precise navigation, high accuracy in time measurements and in computation are necessary.

The problem was to measure time to a maximum error of 0.01 microsec. This meant a rise time of 0.1 microsec for the transmitted pulses and a receiver automatic gain control to consider differences in ranges to the ground stations. Also, the error in relaying a pulse at the ground slave station would have to be less than 0.01 microsec. Automatic tie-in with aircraft control surfaces, and conversion from hyperbolic to rectangular coordinates for navigation—a nasty computation—had to be performed.

The automatic time measuring device was singled



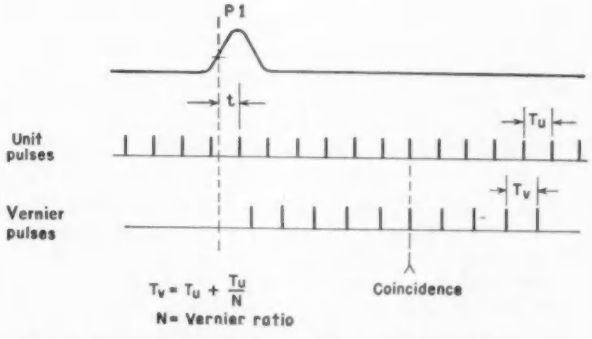
A possible arrangement of radio transmitters for a hyperbolic guidance and navigation system (like Loran). FIG. 1

out as the heart of the system—the critical component on which the success of the system depended—and the initial effort was concentrated on this problem. Don Burbeck, who had previous experience with Shoran systems, got this assignment. Within a week or so he came up with a novel and promising scheme that set a lively pace for the rest of the project. The idea was to extend a vernier system into the fourth dimension—time—by using pulse sequences and counting techniques.

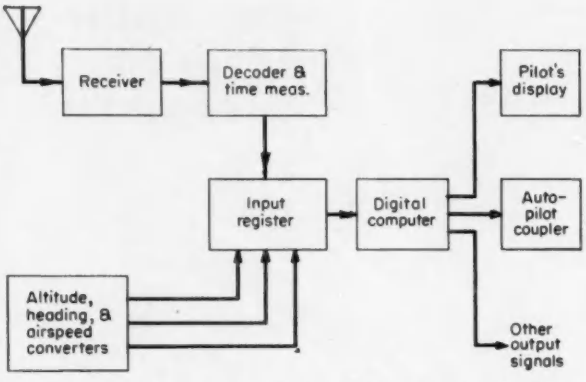
THE TIME VERNIER

A 2-megacycle oscillator generates a continuous train of pulses for a linear time scale, and counting these pulses gives a time measurement to the nearest ½ microsec. To measure a fraction of a standard spacing, a vernier scale must have a slightly different spacing (e.g., a 9:10 ratio in a decimal vernier). For time the scale must differ in frequency and an interpolation is made by counting vernier pulses to coincidence with a standard pulse. The vernier pulses are derived from a pulsed ringing circuit, triggered by the incoming timing pulse. Pulsed crystals were used until simple ingenious pulsed LC circuits with the necessary stability were developed. The method illustrated in Figure 2 measures the fractions of a ½ microsec interval which occur at the beginning and end of each time difference. The frequency ratio is 31:32, giving an average accuracy of plus or minus 0.008 microsec on individual measurements.

Both analog and digital techniques were considered for computation, but digital time measurements of high accuracy prompted the decision early in 1949 to build a general purpose digital computer for the air-borne system. Besides high accuracy a digital computer has the following advantages: the problem formulation may be modified at any time during de-



The vernier method applied to time measurement. Exact timing of P1 between unit clock pulses is found by counting to coincidence with vernier pulses that have a known ratio to unit pulses. FIG. 2



Digitac system measures time differences in signals from ground stations and computes position. FIG. 3

velopment, construction, or test, without changing the equipment design of the computer; programming control decisions to permit different control operations such as a pre-planned course of flight, homing on a target, return to base, etc., is easier; and a standard general-purpose machine for many different airborne systems could be mass-produced out of identical sub-assemblies—an intriguing prospect.

AIRBORNE DIGITAL COMPUTERS

Electronic digital computers up to 1949 had involved rooms full of equipment and thousands of tubes. This posed a problem for an airborne computer, whose stringent conditions of operation impose limitations on size, weight, power, and cooling.

Other new problems introduced by the choice of digital computation were:

- analog to digital conversion for inputs and outputs
- the effect of discrete signals and finite computation time on aircraft control
- programming the system equations

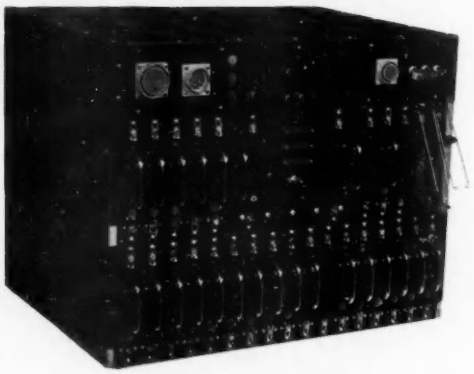
These critical problems and others previously recognized were studied for feasible solutions.

By the end of 1949, an 8-digit serial-binary digital computer with a small magnetic drum had been constructed and operated, and confidence grew that a practical airborne digital computer could be built by time-sharing computer circuitry using crystal diodes to replace tubes. The final study report recommended the system shown in Figure 3.

It took some forward looking Air Force men, like S. B. Neister of the Armament Laboratory, WADC, to recognize the potential value of this project and to support it. Three ground stations and two duplicate airborne systems were built. About 30 per cent of this development was concerned with the digital computer (see Figure 4). The serial magnetic drum computer has a word length of 16 binary digits plus sign and a digit frequency of 100 Kcps. The magnetic drum has storage space for 768 orders, 192 numerical constants, 96 numbers used in intermediate computation, and a 6-word fast-access register (Figure 5). The order code consists of 37 operations of which 24 are associated with the inputs and outputs. The remainder are the normal arithmetic operations of addition, subtraction, multiplication, division, and associated transfer operations.

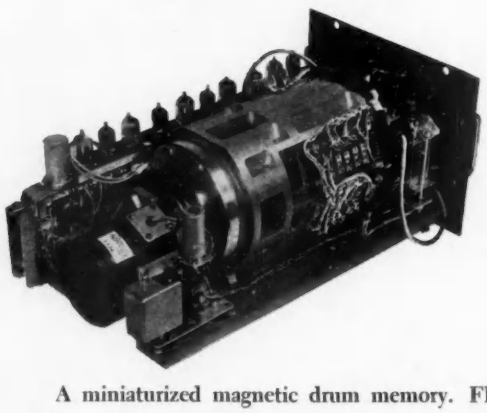
The structure of the order code is shown in Figure 6. A novel equipment-saving feature of the design of the digitac computer control is that the address or location of a word in the storage is given relative to the last operation rather than to some origin point.[1] In this "floating address" system, word spaces are counted from the previous order to the number desired in a given storage band (a pair of tracks). After the operation is completed the computer then counts words to the next order. The second part of the order-word specifies both a number track and a corresponding order track (these are physically separated magnetic heads).

THIS COMPUTER WAS DEVELOPED



The airborne digital computer. FIG. 4

...AND IT EMPLOYED A COMPACT MEMORY



A miniaturized magnetic drum memory. FIG. 5

A three-channel automatic gain control was developed for the receiver. This stores the average level of the last half dozen pulses from a given ground station and switches to the receiver the proper gain in anticipation of signals from each of the ground stations. The repetition rate is 300 pulses per sec.

In this computer, the pulse rate set by a timing track on the drum (i.e. drum speed) is not accurately controlled. It is necessary, however, to know the solution time precisely to determine an accurate ground speed. This is done by using the time measuring equipment to measure the magnetic drum speed. The computation time then can be computed accurately with an over-all saving in airborne equipment.

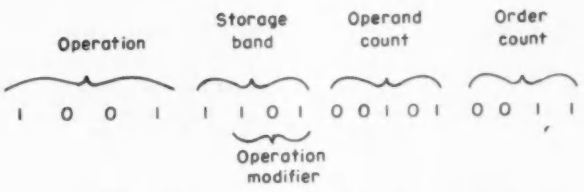
DIGITAL AIRCRAFT CONTROL

For digital control of an aircraft, two characteristics of digital computation are important. First, it takes a finite time to complete a computation of the control function. This introduces a delay, which may cause control instability. The magnitude of the delay depends on computation speed, problem complexity, and programming skill. The second characteristic which can cause trouble is that the computer output may fluctuate violently either as a result of a computation error or rough input data.

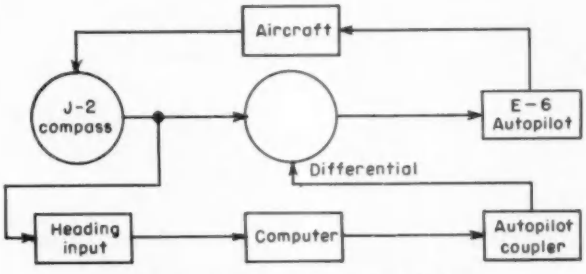
Computer errors can be rejected best by analog filtering of the computer output, although this results in an increased delay. One way to use the computer is to put it directly into the autopilot loop. In this position, the computer must pass all frequencies handled by this loop, some of which are many times higher than those associated with changes in desired heading——posing even more stringent requirements. In the Digitac system the computer is placed outside the autopilot loop. Thus, computer output can be heavily filtered to minimize the effect of spurious transients, with no effect on the autopilot stability.[2] (See Figure 7).

Figure 8 shows the autopilot coupler. A bi-directional notching motor drives the differential synchro. The shaft revolves 1/50th of a revolution for each applied voltage pulse and is locked in position at all other times. A reversing relay determines direction of rotation. The notching motor is coupled to the differential synchro through a 36-1 gear so that each pulse applied to the motor corresponds to a heading increment of $\frac{1}{5}$ deg. The pulses go to the notching motor through the gating circuit except when the count in the register is zero. The computer shifts a 7-digits-plus-sign number into the register. The pulse rate is proportional to the steering signal.

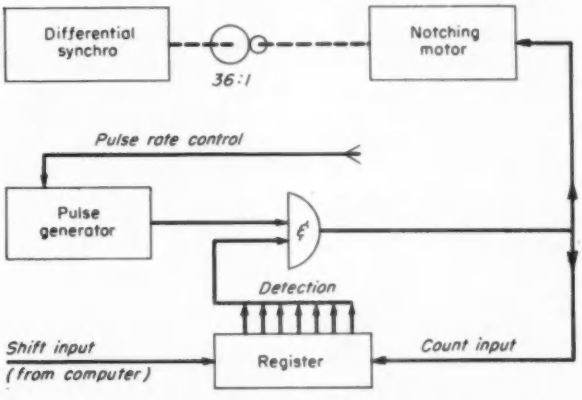
An iterative technique solves the position problem. It uses the previously computed velocity and position data in each cycle to compute a predicted position. One half of this predicted position is combined with one half of the current time measurement to get a new smoothed position value. To smooth the wind signal, $\frac{1}{32}$nd of the computed wind value



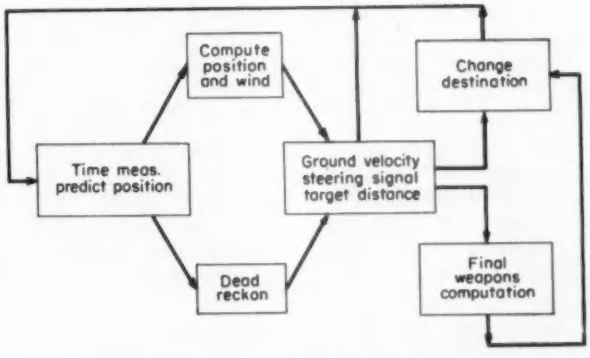
Digitac uses a serial order code, with a "floating address" in which words are located relative to the last operation rather than some origin. FIG. 6



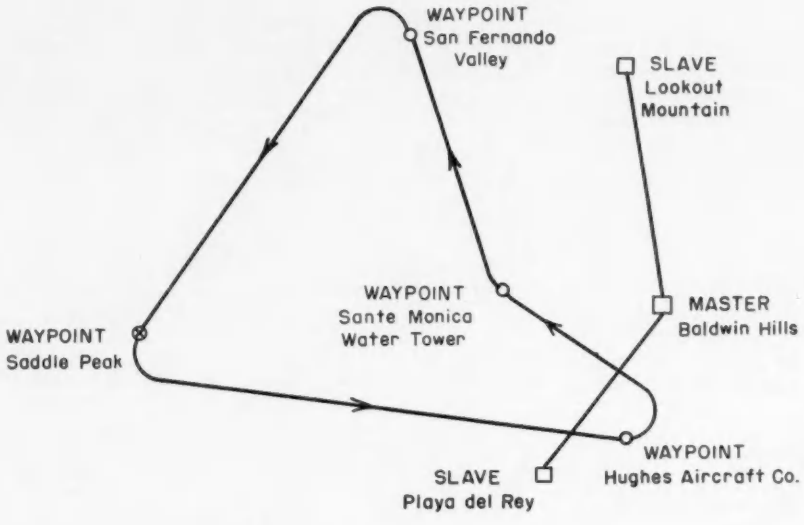
Digital computer is not in autopilot loop; does not introduce control lags. FIG. 7



Computer controls autopilot synchro input via a bidirectional notching motor. FIG. 8



Typical problem handled by Digitac. FIG. 9



FLIGHT TESTS PROVED DIGITAC

Course navigated by computer in original flight tests. FIG. 10

is combined with $\frac{3}{32}$nds of the previously smoothed wind to get the prediction. Thus the wind is heavily damped, so that 20 to 30 sec are needed to reach a stable wind value.

HOW DIGITAC WORKS

As the flow diagram indicates, Figure 9, the computer routine begins with an order for the two time measurements and may follow several alternate loops. The heavy line loop is the normal navigation iteration consisting of 1) time measurements and position prediction, 2) position and wind computation, and 3) computation of ground velocity, steering signal, and target distance. This routine has 360 instructions, takes 0.5 sec, and provides an aircraft steering signal. Aircraft instrument measurements are picked up as needed.

At the beginning of each cycle the computer examines the time measurements and if either value is unreasonable due to signal loss, noise, etc., the data is discarded and the lower dead reckoning branch is followed. The dead reckoning branch uses past computed position, wind, and current instrument data to predict present position. The other two branches of the program are employed after steering signal computation as the target is approached for final weapons computation and change destination—or for change destination only.

A total of 700 instructions are required for complete navigation and weapons computation. Computing time for the dead reckoning was 0.3 sec, and since iteration time was held at 0.5 sec, there remained 0.2 sec dead time. Computations for weapons control were solved in this additional 0.2 sec without decreasing accuracy of control.

PROVEN BY FLIGHT TEST

After extensive laboratory tests, during which the program and equipment were debugged, the system was flight tested in a C-47 aircraft[3]. The first flight was made in June 1952 and tests continued for 14 months over a test range in the metropolitan area of Los Angeles. The ground stations were at Playa del Rey, Baldwin Hills, and the Hollywood Hills. One flight a week was the average, for a total of 55 flights and 92 hours in the air. The system accuracy was checked by aerial photography.

In a number of automatically controlled flights, the system navigated through a series of four waypoints as in Figure 10. The automatic computer control was found smoother and more accurate than manual control. The computation iteration time of $\frac{1}{2}$ sec did not cause instability; in fact, stable control was obtained with longer iteration times.

The Digitac program proved that airborne digital computers are practical, not only for the control functions of the system, but also as the central computing point for a variety of auxiliary computations like cruise control, air data reduction, predicted time of arrival, and other problems.

These developments carry implications for the industrial field. The day is not far off when small, general-purpose computers will be available at a reasonable price for process control work.

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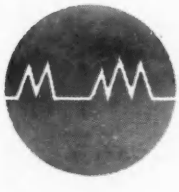
INTRODUCING

A Dual Series of Articles on Digital Theory and Application for the Control Engineer

In recognition of the growth and importance of digital data processing, CONTROL ENGINEERING's *editors have integrated two series of articles by a group of outstanding authorities in the digital field.*

THE BASIC DIGITAL SERIES:



A group of ten articles that will cover the theory of operation of digital systems and evaluate the various functional elements of data processing. The first article, which starts on the next page, takes a broad look at how data processing works. Subsequent articles in the series will deal with the theory of numbers, logical design, arithmetic elements, storage, basic programming, etc. They will give the apprentice designer or the potential user of data processing systems a meaty introduction to the digital field.

THE DIGITAL APPLICATION SERIES:

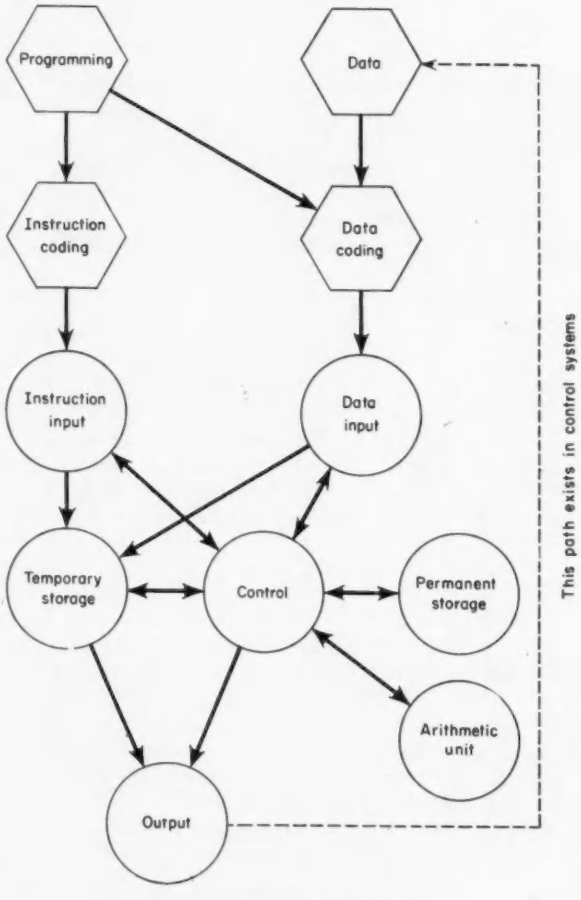
A group of fourteen articles that will cover the selection and application of data processing equipment and systems. Following next month's introductory article on application by Dr. Eugene M. Grabbe, the series will cover programming, system design, and equipment, in three basic areas: 1) solving scientific problems; 2) handling business data; 3) controlling a process. Prime attention will be given to how the equipment is used, rather than how it works.

ABOUT THE FIRST ARTICLE:

Author Jerre D. Noe introduces the reader to the over-all picture of data processing and discusses how data processing can replace a conventional, or manual, information system. He does this by solving three simple hypothetical problems both manually and automatically. Three unique system diagrams clearly relate each basic digital function to everyday techniques.

Data Processing Systems: How They Function

JERRE D. NOE, Stanford Research Institute



General functional relations in automatic data handling systems. FIG. 1

Contrary to some of the popular literature, digital computers are not "giant brains" in the sense that they have powers to undertake and automatically solve all problems that one might conceive. Instead, if a name is necessary, it might better be "giant slaves". Digital computers are essentially means for mechanizing repetitive operations—operations that can be precisely defined and that need repeating over and over again—operations such as are frequently encountered in scientific calculations, in business data-handling problems, and in the control of dynamic processes. The computing machines that exist today must be instructed in great detail and this imposes a considerable burden on those who initially plan for their use. However, once the planning is done, they are capable of handling a tremendous amount of detailed work.

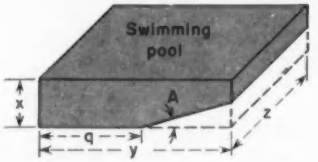
Units in these automatic data handling systems are capable of storage, calculation, control, and communications, and the general interrelation of these elements is basically the same, regardless of application, Figure 1. The functions named exist whether the system is manual, in which case the work is done with desk calculators, or mechanized, so that it can be entered into an automatic computer.

Since there is an essential sameness about function, one way to explain the fundamental operation of an automatic system (and the functional components that make up a system) is to compare the manual and automatic methods of solving the same problems. Before proceeding into the detailed discussions of computing system elements in the articles to follow, it is possible to get through this comparison a feel for the functions of these elements since these functions are similar to those of well-known techniques and devices. Thus, the arithmetic unit of a data-handling system might be compared with a manual mechanical calculator, and the permanent storage unit with a set of trigonometry tables.

To accomplish this comparison, three systems are shown in their manual and automatic versions. So

SOLVING A SCIENTIFIC PROBLEM FIG. 2

HOW IT'S DONE MANUALLY



HOW IT'S DONE WITH AUTOMATIC COMPUTING MACHINERY

PROBLEM – What is weight of water in full pool for various dimensions, angles of slope and densities of salt water?

$$W = \left[xyz - \frac{(y-q)^2 \tan A}{2} z \right] w$$

Programming

Input data from temporary storage

Arithmetic unit

Permanent storage

Checking

Boundary conditions

1. x can range from 3 ft to 10 in 1 ft increments
2. y can range from 10 ft + increments

Natural Trigonom

Operator control function

Supervisor spot checks values or Calculation is duplicated

Programming

Instruction coding

Delay line

Flip-flop

Magnetic drum

Temporary storage

Data coding

Data input

Output

Magnetic tape

Punched cards

Graphically

Control

Arithmetic unit

Prewired circuits

Plugboard

Permanent storage

Checking

that attention can be focused on system functions rather than problem details, the three cases are purposely kept very simple. Of course, the same line of thought can be extended to complex situations of the type where the advantages of automatic data handling become more obvious. The problems are selected to cover pretty well the principal areas of computer application: one scientific problem, an inventory-control system, and an air traffic control system.

SOLVING A SCIENTIFIC PROBLEM

Consider the manual operations that must be performed to solve a mathematical problem, Figure 2. Starting at the top of the figure, the mathematician must first perform a function that might be called programming. He breaks the original problem into a form suitable for solution by the means at hand, be it manual or automatic, and then gives an adequate description of the steps that must be followed. In the case of manual computation, "programming" often means titling columns in which intermediate results are to be written.

The next step in the operation, "coding," is not needed in the manual case. The operator of the desk calculator can understand the words and symbols used by the mathematician; hence it is not necessary to translate from the language of the mathematician to the language of the operator.

In the manual system, the input is verbal instructions to the operator plus equations and boundary conditions that are written on paper. The paper is in a sense a part of the temporary storage required for the process. The operator, of course, performs the control function in the diagram. When he has been given the description of the problem and the data essential to its solution, he goes to the arithmetic unit, i.e., desk calculator, drawing upon the information in temporary storage as required by the equation being solved. He may also, when necessary, draw information from permanent storage, which might consist of tables of functions. As the calculation proceeds, intermediate and final results are written out in the form of tables or plotted in graphical form.

In any such calculation, it is necessary to check the results. This is usually accomplished by comparing easily pre-calculated check points with the final results and by duplicating the calculation at various points, applying different methods.

Now look at how the scientific calculation can be carried out in an automatic computing system. This is shown on the right side of Figure 2. The steps are much the same, although the functions may be provided by apparatus that differs markedly from that used in the manual case.

The programming operation again involves breaking the problem into a form convenient for the computation method and the computing device being used. It provides a precise and detailed specification of all the steps that are to be taken and the order in which they are to be accomplished. To minimize the number of instructions that must be given to the computer, this programming often makes maximum use of iterative steps, i.e., the computation pattern is repeated over and over, each time more closely approaching the correct result.

The programming instructions must be converted into a form that can be interpreted by the automatic system and must be so stored that all steps are available to the machine as needed. This information must be described in terms of a unique code that the computer is designed to interpret.

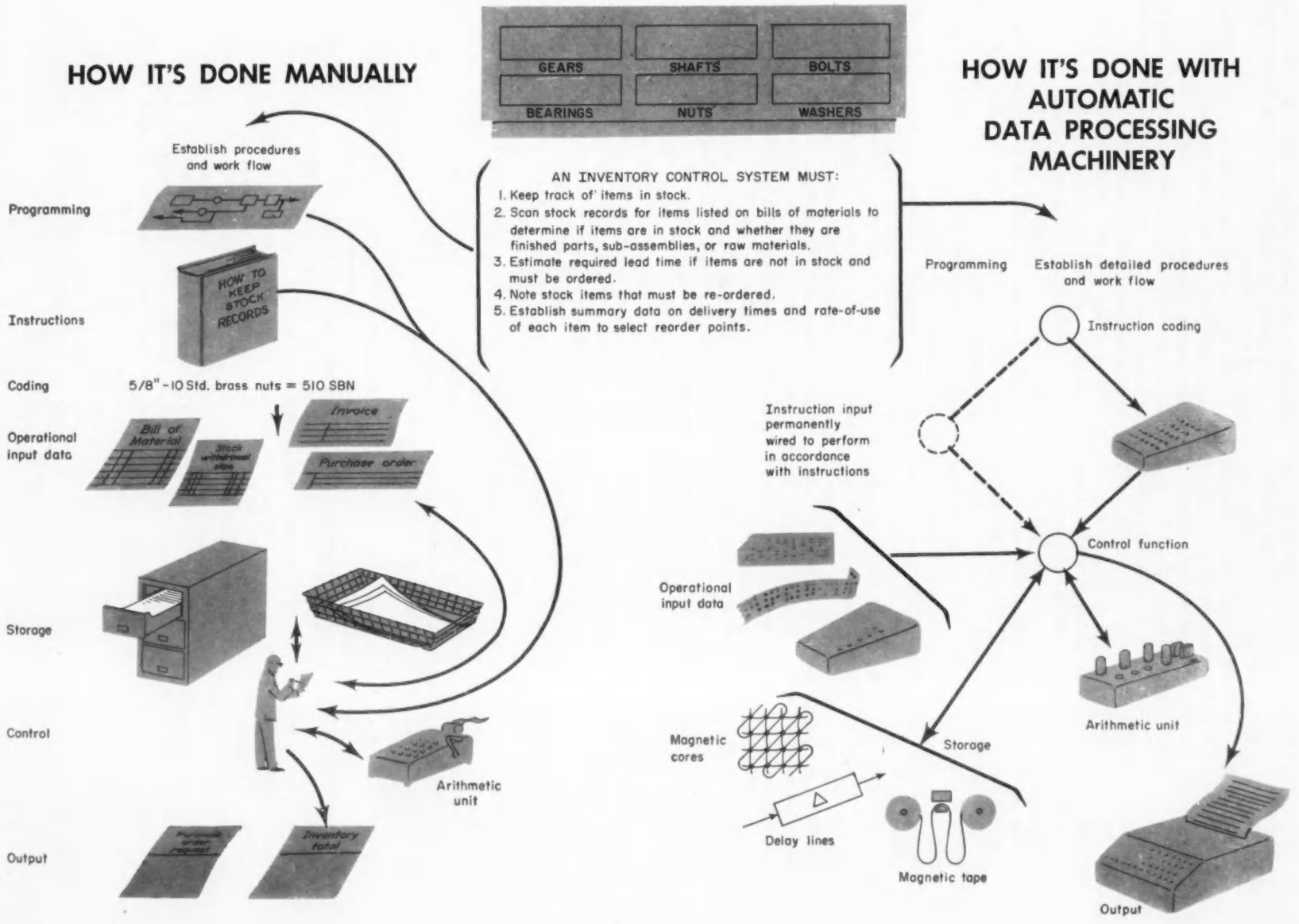
Having gone through this stage, the information is ready for the input operation. All instructions and boundary conditions are entered, in accordance with the pre-determined format, through a keyboard, punched paper tape, or other input medium. Note that in scientific calculation, there is seldom any great distinction between the instructions and the data since the amount of data normally required is relatively small. Hence separate input devices are usually not necessary. Once entered, the information may be placed in a "quick access" storage medium, such as vacuum tube registers, electrostatic tubes, mercury lines, magnetic drums, or other devices with a limited storage capacity that can deliver their stored information on fairly short notice.

After this step, the operation can be carried out by the control unit, which consists of circuits capable of making logical choices. These circuits are connected and sequentially controlled by the programmed instructions retained within the temporary storage unit. In carrying out the required operations, the control unit will make use of other logic circuits combined into a system capable of performing arithmetic operations and it may find it necessary to draw information from a "permanent storage" device. This permanent storage may consist of plug boards and circuits pre-wired to carry out various logical operations, or of a photographic memory storing a large volume of information.

As the calculation proceeds, intermediate and final results are transferred to the output device. The output may be delivered as coded information on magnetic tape, punched cards or other media, or may be converted directly into printed tables or graphs. Again, it is essential to check the operation of the computing system. The methods used in manual computation are available for this process, i.e., duplication of calculations, using different methods. It is possible also to follow the accuracy of the data during calculation with redundant codes.

These comments emphasize the nature of jobs that lend themselves to automatic computation. To be placed on automatic computers, the problem must be such that general decisions can be made in advance, i.e., rules can be established. The

PROCESSING BUSINESS DATA FIG. 3


GEARS
SHAFTS
BOLTS
BEARINGS
NUTS
WASHERS
HOW IT'S DONE MANUALLY
HOW IT'S DONE WITH AUTOMATIC DATA PROCESSING MACHINERY
AN INVENTORY CONTROL SYSTEM MUST:
1. Keep track of items in stock.
2. Scan stock records for items listed on bills of materials to determine if items are in stock and whether they are finished parts, sub-assemblies, or raw materials.
3. Estimate required lead time if items are not in stock and must be ordered.
4. Note stock items that must be re-ordered.
5. Establish summary data on delivery times and rate-of-use of each item to select reorder points.
Establish procedures and work flow
Programming
Instructions
HOW TO KEEP STOCK RECORDS
Coding
5/8" - 10 Std. brass nuts = 510 SBN
Operational input data
Bill of Material
Stock withdrawal slips
Invoice
Purchase order
Storage
Control
Arithmetic unit
Output
Inventory total
Programming
Establish detailed procedures and work flow
Instruction coding
Instruction input permanently wired to perform in accordance with instructions
Control function
Operational input data
Arithmetic unit
Magnetic cores
Storage
Delay lines
Magnetic tape
Output

problems that can be handled best are those that involve a large amount of repetitive work. And to compete economically, the volume of work must be so great as to make it difficult to use human labor, due to time limitations or the expense of placing large numbers of people on a job and effectively coordinating their efforts.

Since there are differences in the types of problems, there must be differences in the types of equipment that should be used in the areas of scientific calculation, business data handling, and control systems. Some of these differences are worth noting. In the case of the scientific calculations, a relatively small quantity of input and output information is required. The problems are characterized by repetitive complex combinations of simple arithmetic operations. The input data remain unaffected by the computation process, and the requirements on time allowable for the computations are usually not too stringent.

Business data handling, on the other hand, deals with large quantities of input and output information that usually is subjected to relatively simple series of arithmetic operations. As in scientific calculations, the information upon which the computations are based remains fixed throughout the processing. More stringent time requirements are usual in the business data handling since it is generally necessary to fit the operations into a daily or monthly time schedule. Most business data handling problems present a programming job that is more complex than for scientific computation. A greater number of "branch point" decisions are required in business problems, especially if many of the "exceptions" within a business are handled.

In a control system, the quantity of input and output data may be comparable to that required for scientific computing. The real differences are to be found in the nature of the data and the time allowable for computation. The input information in the control system is variable and may change due to external causes or because of the control system itself. The whole operation must be done on a "real time" basis, since solutions must be computed and used in a time short enough to provide control and keep the system stable.

HANDLING BUSINESS DATA

As an example of business data handling, consider an inventory system used by a production organization, Figure 3. The system must be set up so that the stock records are available when needed and so that these records can be altered as items are entered or withdrawn from stock. When a bill of materials is made out for a production run, it is necessary to scan the stock records for those items listed on the bill, to find those items that are in stock (whether they are finished parts, sub-assemblies, or raw materials), and to determine what items must be ordered for the production run. For these latter items, estimates of the required lead-time must be provided. Also, stock items must be re-ordered.

In addition to these routine operations, the stock-control system must provide summary data on delivery times and the rate of use of each item, so that reorder points can be established. And it must produce stock totals when necessary for checking against physical inventory.

Whether this operation is manual or automatic, someone must establish the work flow and the manner in which the job is to be done. However, in planning for an automatic system, it is necessary to go far beyond the establishment of broad directives. It is essential to describe in detail each step in every operation to be carried out. This must be done with a complete knowledge of the capabilities and limitations of the automatic equipment and of the kind of instructions the equipment can interpret. This, again, is the programming function.

The next operation, coding, does not exist for the manual operation in the sense of language translation required to communicate with the personnel who are doing the work. There may, however, be a small amount of coding for the purpose of convenience; for example, stock numbers may be used. In the automatic case, it is necessary to code all instructions and all data in machine language.

When programming and coding are completed, the instructions must be fed into the system. In the manual case, this is done by procedure manuals and training programs describing the stock control system and the general flow of work. In the automatic case, the instructions are entered into the system through keyboards or other input devices. Or they may be established by the manner in which the automatic system is wired. Operational data are entered in the manual system through bills of materials, invoices, copies of purchase orders, stock withdrawal slips, shipping notices, etc. The same information goes into the automatic system either on specially prepared forms from which the information can be scanned automatically, or on punched cards, keyboards, or similar devices.

The storage function in the manual case is physical storage of the paper on which the data arrives. This is kept in baskets, file cabinets, or in quick-reference cards, such as the Kardex System. Storage for automatic systems is provided by devices such as acoustic delay lines, magnetic cores, and magnetic tapes. In conjunction with this, the system might store by automatically handling the actual paper involved, coded to be read by automatic means.

The control function is provided by the stock room personnel, in the one case, or automatic control circuits under the influence of wired stored instructions, in the other. This control handles the flow of data between the input, output, storage, and arithmetic units. Operations such as calculating stock levels and reorder points may be done

with desk calculators in the manual case, or with automatically-controlled arithmetic circuits.

The output, in the form of requests for purchase orders, inventory totals, and similar items is summarized and typed by the stock room personnel in the manual system or automatically summarized by scanning the memory systems of automatic data-handling equipment. The required information is printed out by the system on demand or on a pre-arranged schedule.

CONTROLLING A PROCESS

The addition of the dotted line between output and data in the diagram of Figure 1 completes the functions necessary in a control system. This order is quite similar to business data processing, particularly in emphasizing the separate channels for processing instructions and for processing the data. The outstanding difference in the control system is the connection between the output of the system and the source of data.

As an example of a control system, consider some of the steps that are necessary in air traffic control. And for simplification, focus on a very small portion of the overall problem—the process of clearing an incoming aircraft into its final approach.

The aircraft contacts the airport and gives its identity, its destination, its position, and its estimated time of arrival at the initial approach area; then it requests instructions. The ground control station must check the data on the schedule of the aircraft and examine the status of the air space and taxi area, i.e., the time assignments for other arriving and departing aircraft. Then the ground control contacts the aircraft, giving identification, altimeter setting, acknowledgement of position, position with respect to other aircraft, instructions on how to proceed (enter initial approach—go to hold pattern) and time at which action is to be taken. Acknowledgement of the control instructions comes from the air and then they are carried out. The estimated time of arrival at the entry to the final approach is sent back, along with a request for clearance for final approach. The ground control again must contact the aircraft, giving time check, position check, position with respect to other aircraft, wind and velocity, the runway to be used, the airport situation, instructions on how to proceed, and time to take action.

Consider some of the steps necessary to implement a manual or an automatic system; that is, to handle the required functions, Figure 4. First, someone must carefully define the problem, and in doing so must consider CAA regulations, local terrain, traffic handling capacity of the airport, characteristics of the types of aircraft that will be handled, decisions that will be forced by weather conditions, and numerous other factors.

When the required functions are clearly outlined, the whole operation is programmed. It is necessary to decide what independent initial events can occur and what must be done as a result. This must be settled in the precise sequence that is to be followed and must include such factors as the speed with which decisions must be made, capacity of communication channels, and so forth. In planning a manually operated system, the "programmer" must be fully aware of the capabilities and limitations of the human operators, as well as the characteristics of the equipment they will use. In programming an automatic system it is again necessary to thoroughly understand the operational capacities and limitations of all units. Furthermore, the programmer must know precisely which instructions can be understood by the system, the amount of storage available, and the time required by the equipment to perform the various steps.

When the programming has been completed, the information must be fed into the system. This is best treated in two separate stages: the entry of instructions that tell the manual or automatic system how to handle the operational data; and the data input itself, through which the detailed information flows to handle a specific situation. For the manual operation, the instructions are imparted to the staff through training programs, instruction books, maps, etc. For the automatic system instructions are entered by the manner in which the system is wired and by introducing coded sequences through a keyboard, punched paper tape, or other medium. These are interpreted by the system as instructions for each chain of events.

When the system has been equipped to take care of all situations, it is ready to accept the operational data; e.g., flight plans, weather information, aircraft location, requests for instruction, information on fuel, aircraft type, etc. In the manual case, the information is accepted by the operators over radio, telephone, teletype, and through radar displays and meter readings. In the automatic case, the same information arrives over the same channels, but it must be converted or coded into the "language" understood by the system. This is accomplished with digital code converters, and analog-to-digital converters capable of translating a shaft rotation or a dc voltage into the machine code.

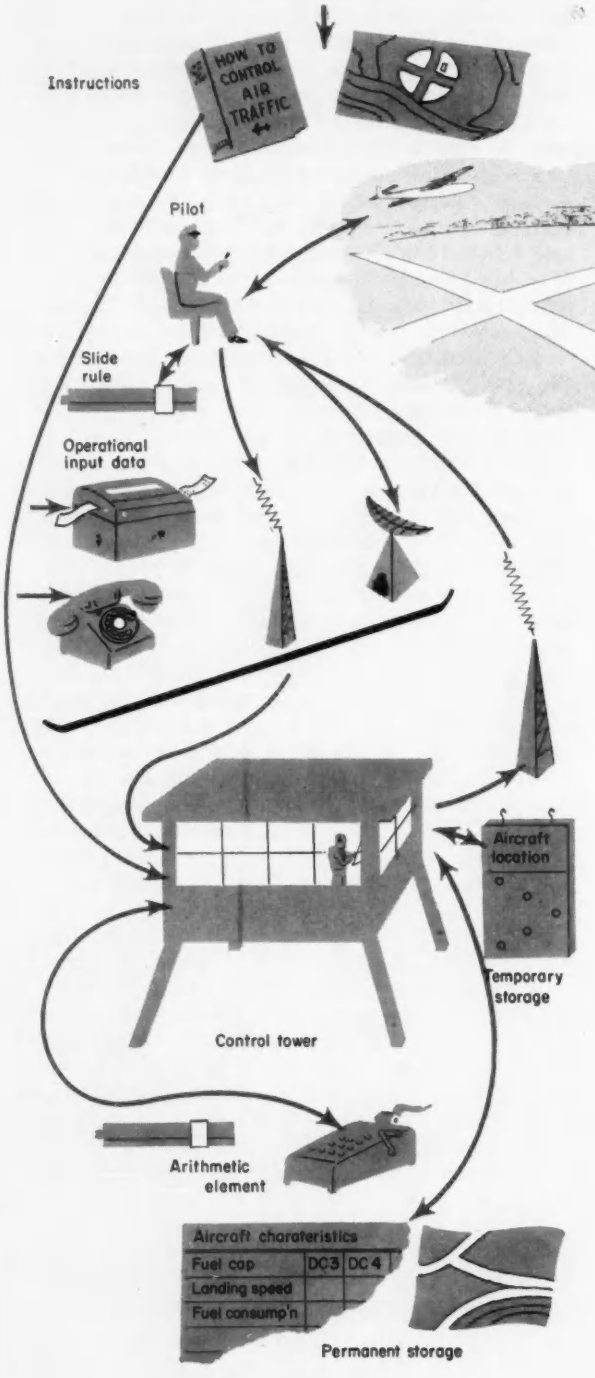
During information processing which is under the control of the operators or the programmed automatic control unit, it is necessary to draw upon temporary and permanent storage and upon means for performing arithmetic calculations. Temporary storage in the manual case is in the minds of the controlling personnel and on display boards. In the automatic case, such storage devices are used as magnetic drums, magnetic cores, acoustic delay lines and other media that can be cleared out or "erased" after each aircraft has been handled. Permanent storage may be necessary to provide data on the characteristics of various aircraft types, or on terrain, holding patterns, traffic patterns, and similar factors. In the manual case, this permanent storage

CONTROLLING A PROCESS FIG. 4

AIR TRAFFIC CONTROL —
Clear an incoming aircraft into the final approach to an airport

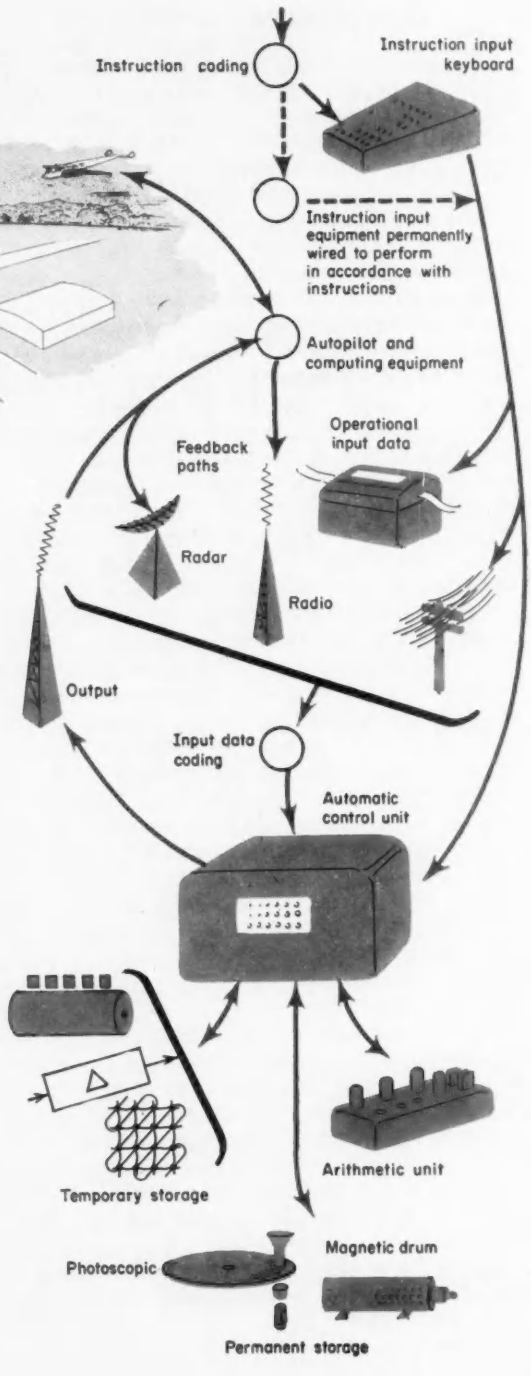
HOW IT'S DONE MANUALLY

PROGRAMMING Determine events that can occur and what must be done as a result. Consider CAA regulations, local terrain, traffic handling airport capacity, aircraft characteristics, etc. and the capabilities and limitations of human operators.



HOW IT'S DONE AUTOMATICALLY

PROGRAMMING Determine events that can occur and what must be done as a result. Consider CAA regulations, local terrain traffic handling airport capacity, aircraft characteristics, etc..



is in the form of printed tables and maps; in the automatic case, magnetic drums are used.

During processing of the data arithmetic calculations are necessary for computing bearings and speeds for a prescribed course, and for estimating fuel consumption during stacking, preparing the estimated time of arrival at various points, and meshing landings and takeoffs. In the manual case, these computations are performed by pilots and operators with special slide rules, nomographs, and other calculating aids. In the automatic case, arithmetic circuits perform the required operations.

Output information must be fed back to the aircraft so that it can be controlled. The manual system uses radio links over which the ground control operator can give verbal instruction to the pilot. The automatic system transmits coded information from ground to air. This information is decoded, either for presentation to the pilot or for direct operation of an autopilot. Often as a result of this transmission the plan that the aircraft is following is altered. It is in this sense that the control system differs from business and scientific calculation. The basic data upon which the system operates is continually changing due to external causes and to feedback from the control system.

A LOOK AT THE SYSTEM ELEMENTS

The above examples touch on many significant areas in the design and application of digital machines. One of the most important is storage. The ability to store information is the most basic function of such systems, and it distinguishes them from simple control and calculating devices. The gross nature of the storage method, e.g., storage capacity and the time required to gain access to stored information, has a great influence on the general character of the automatic computing system. The *detailed* nature of the storage method—such as the number of different "states" or conditions in which each memory cell can be left—affects not only the types of circuits, but also the system of arithmetic used within the system. As a prime example of this point, note that most digital computers use some form of binary code for their internal operations—that is, they operate in a number system that contains only the numbers 0 and 1, rather than the decimal numbers 0 through 9. This is not done because of any inherent advantage of the binary system. Rather, it is because high-speed two-state-memories are available and memories that can store ten different states are impractical.

The arithmetic and control operations represent another area of great importance. Certain basic arithmetic and control operations can be built into the system, and more complex operations can be evolved by combining these in a carefully developed sequence. This raises a number of questions about the design and application of automatic computing systems. For example, what building blocks—i.e., basic operations—should be designed into a machine for a given field of application? How can the problems that are to be solved be broken into combinations of the basic arithmetic operations? What method of control is best for a given machine?

Input and output equipment is also worthy of attention. There are many ways in which information can arrive at the input of automatic data handling systems. It can be recorded in coded form on photographic film, punched paper tape, punched cards, magnetic tape or other devices; it can be printed in arabic and alphabetical characters in a form that can be scanned and interpreted automatically; or it can arrive as shaft rotations or as electrical waves on communication lines. Similarly, there are many methods of obtaining the output information from a digital system. These methods differ in speed, convenience, accuracy, and cost, and careful study must precede choice of a system.

These topics and many other important aspects of automatic computing, control, and data-handling systems will be treated in the forthcoming series of articles.

JERRE D. NOE

As Assistant Director of the Engineering Research Div. of Stanford Research Institute, Menlo Park, Calif., Jerre D. Noe supervises engineering research and development of electronic data handling systems. He joined the institute in 1948, the same year that he received his PhD in Electrical Engineering from Stanford University. Between 1944 and 1948 he accumulated experience in his field as research associate in the American-British Laboratory in Malvern, England, and in the Radio Research Laboratory of Harvard University, and through his work in the development laboratories of Hewlett-Packard Co., Palo Alto, Calif. He served on the Joint Computer Conference Committee in 1953-54 and on the National Administrative Committee of IRE's Professional Group on Electronic Computers in 1954. He currently is National Vice-chairman of PGEC.

A NOTE ABOUT COLOR AND CONTROL: Color is a complex phenomenon and therefore not simple to measure and control. Yet we live in an age of color. A color-conscious public demands much: color must match; color must harmonize; it must create moods—attract, repel, cool, or warm.

For the control engineer all this adds up to measurement of color, specification of color, tolerances, regulating color in production, and automatic control, if possible. But to measure color he must have a basic knowledge of the science of color and a familiarity with working color systems. Part I of this discussion explains the scientific basis of color and outlines the leading color notation systems. And Part II, to follow next month, will summarize the various types of instruments used for measuring color.

Color Basics for the Control Engineer

PART I: THE FUNDAMENTALS OF COLOR

O. H. OLSON, Armour Research Foundation

We will start by defining color in the language of a block diagram, shown in Figure 1, and then consider each of the system's four "components".

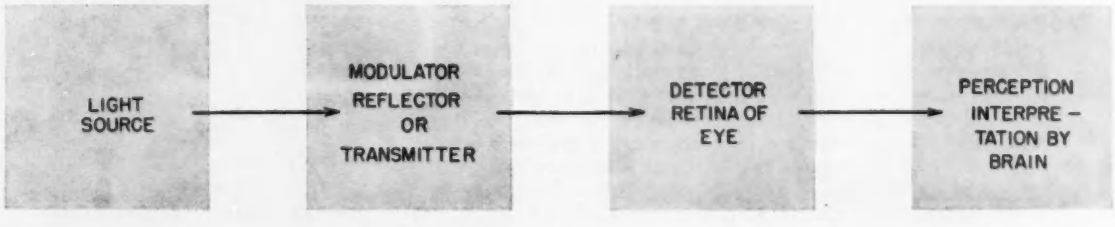
1—The Light Source

The source of all color is visible radiation or light. Without light there is no color. Light is electromagnetic radiation, as are ultraviolet, infrared, heat radiation and radio waves, but is restricted to a narrow band of wavelengths between 400 and 700 millimicrons. This is the band to which the human eye is sensitive and we call it "light".

Light sources differ in the amount of energy they emit at different wavelengths. Most common sources supply radiation at all wavelengths in the visible range: these are continuous sources and are exemplified by the sun and incandescent lamps. Figure 2 shows the spectral distribution of energy of a number of continuous as well as some discontinuous sources. Mercury and sodium arcs (Figure 2c) are typical of the latter. They emit radiation in discrete lines at some wavelengths and no radiation in other regions. Fluorescent lights, on the other hand, emit a combination of continuous and line radiation.

It is interesting to note that sodium emits only radiations of 590 millimicrons in the visible part of the spectrum: an object illuminated by such a light

FIG. 1



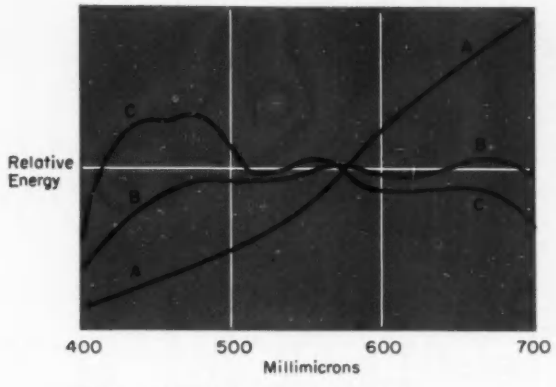


Figure 2(a) ICI Illuminants A, B, C.

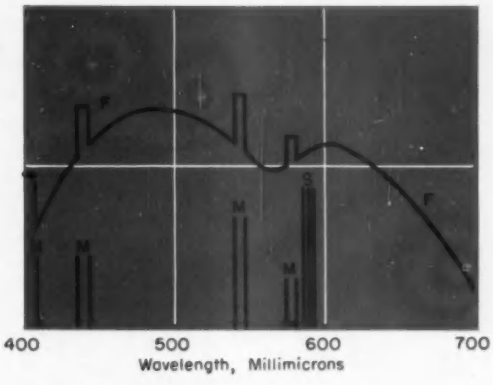
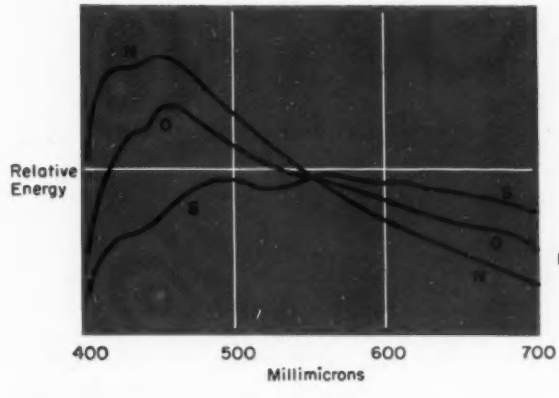


Figure 2(c) M, Mercury arc
S, Sodium arc
F, Fluorescent bulb



Violet	400	— 450	millimicrons
Blue	450	— 500	
Green	500	— 570	
Yellow	570	— 590	
Orange	590	— 610	
Red	610	— 700	

Figure 2(b) S, Sun
O, Overcast sky
N, North sky

Spectral curves for some light sources. FIG. 2

can reflect only this wavelength because none other is incident on it. Sodium arcs are used for highway lighting because they are highly luminous. But sodium-lit objects lose their natural color—they become either yellow or dark. Complexions are sallow under mercury light because mercury emits no red. Incidentally, the color corresponding to wavelengths in Figure 2 changes continuously as the wavelengths go from 400 to 700 millimicrons. But, for convenience, the spectrum colors have been named and placed by the charts.

2—The Modulator

When light from a source strikes a material object some of it is reflected, some is transmitted, and some is absorbed. Thus an opaque object (zero transmittance), which is normally red, may reflect radiation at all wavelengths, but much more in the long wavelength region.

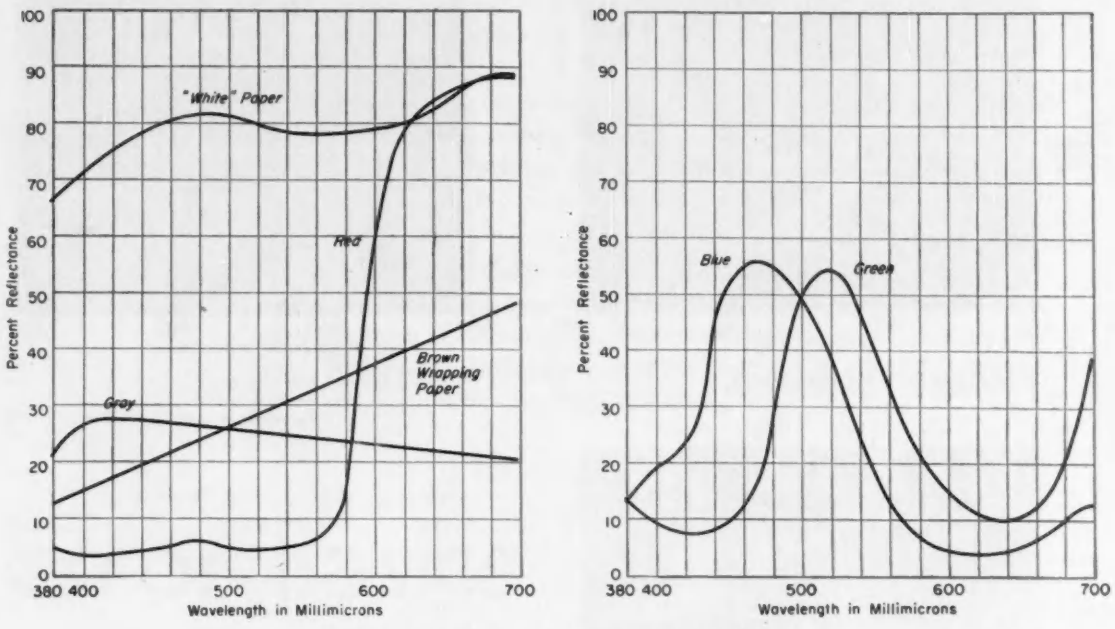
A complete spectral distribution curve is necessary to show in detail how an object reflects radiation at each wavelength. A number of such curves are shown in Figure 3—for "white" paper, brown wrapping paper, red, green, blue, and gray.

On the chart of Figure 3 a perfect white would be a horizontal line at the 100 per cent level, and a perfect black a horizontal line at the zero per cent level. All practical colors are more or less displaced from both of these extremes. The "white" paper reflects about 80 per cent of the visible radiation incident on it, the gray only 25 per cent. Neutral colors such as whites and grays have nearly flat curves whereas chromatic colors display selective reflectance and their curves rise and fall quite steeply.

3—The Detector

The detector of light and color is the retina of the human eye. When light strikes the retina, the cone and rod receptors generate minute electric currents that are conducted to the brain. It is not completely understood how the eye mechanism responds to light in various parts of the spectrum, but it is well established that human vision is trichromatic. By this is meant that three specific receptors in the human eye account for man's ability to see the whole gamut of colors. (See discussion below of tristimulus colorimetry.)

The human eye is an extremely sensitive detector. Under good viewing conditions it can probably distinguish from five to ten million separate colors.



Spectral distribution curves for various colors. FIG. 3

And it is especially sensitive in comparing two adjacent colors and detecting minute differences.

However, the eye is not nearly so sensitive to color difference if two colors are separated either in space or time: color memory is poor. Still, the great sensitivity of the eye is worthy of careful study by designers and users of color measuring instruments.

4—The Perceptor

The experience we know as color or color perception results from an integration process in the brain. The stimuli can be described objectively, as was the material in the preceding sections. But *perception* of color is psychological and defies normal objective treatment. We cannot explain how or why one spectral distribution of radiation is interpreted as red, another as blue, etc. It is known, however, that a certain amount of conscious effort is required to translate an image on the retina into a mental image with shape, size, and color. A good example is a common experience: spending an evening with a friend and not being able to recall afterwards the color of his necktie. The image was certainly on the retina many times. But the conscious effort was missing.

For the control engineer the most important psychological factor with respect to color is the three-dimensional nature of color experience. It certainly is the most fundamental concept for the engineer to grasp and appreciate if he uses and works with color in production. For it helps to explain why color is generally not easy to measure nor simple to specify.

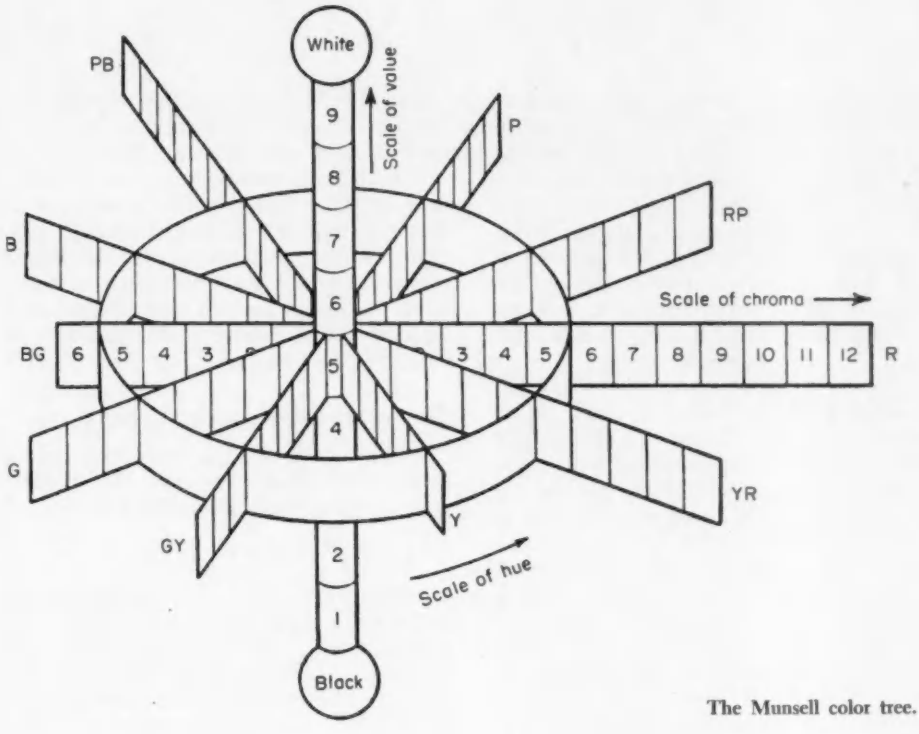
A complete psychological color description involves three attributes: hue, lightness, and saturation. Hue is that attribute which permits color classification according to its similarity to a spectral color such as red, yellow, green, blue, etc. Neutral black, gray, and white do not possess the attribute of hue and some would call them colorless. In color science they are included in the family of colors but belong to the achromatic series to differentiate them from the chromatic colors, which do possess hue.

Lightness is the term that describes the overall luminous effect of a color. It permits a color to be classified as equivalent to one of the gray series. Pink is high on the lightness scale and maroon is low. Yet they both have the same hue, namely, red.

Saturation is that attribute of color that causes it to differ from a gray of the same lightness. Colors of the same hue and lightness may be arranged in degrees of saturation: from gray having zero saturation to a member in which hue stands out very prominently. Olive drab, old rose, and terra-cotta are low saturation colors. Fire engine red, lemon yellow, and grass green are high.

COLOR INTO NUMBERS

Since color experience is three dimensional, it is possible to arrange colors in geometrical space, where each point requires three variables to specify its position. Thus, a one-to-one correspondence is established between colors and points in space. A number of systems have been developed to do this, each possessing certain advantages depending on the



The Munsell color tree. FIG. 4

dimensions chosen for color space. The best known in this country are the Munsell Color System, the Ostwald System and the ICI System.*

The Munsell Color System

The Munsell system best illustrates the three dimensional nature of color experience. Munsell referred to the three attributes of color as "hue", "value" (lightness), and "chroma" (saturation). These were arranged in a color solid somewhat resembling a tree. The trunk of the tree contains the value scale—neutral grays ranging from black at the bottom to white at the top. The different hues are arranged circularly around the trunk in spectral order: red, yellow, green, blue, purple. Increasing chroma is arranged along the branches of the tree from zero at the trunk to maximum at the tips.

Each of the directions of the Munsell tree is divided into visually equal steps. Thus, the trunk starts with a perfect black at the bottom (Munsell Value 0) and ascends through a series of grays to a perfect white (Munsell value 10) at the top by means of ten visually equi-valent steps. The circular hue scale is divided into five principle hues and five intermediate hues so that ten visually equi-distant hues are angularly spaced around each neutral point. Each of the latter is subdivided further into ten parts. And the branches are also marked off in steps to correspond to visual increases of chroma. Figure 4a shows the skeletal structure of the Munsell tree.

* *ICI (International Commission of Illumination) will be used throughout this article because it is more familiar although CIE (Commission International de l'Eclairage) was adopted in 1951.*

Munsell notation is written like a mixed number consisting of a whole number and a fraction, as follows: HUE $\frac{\text{VALUE}}{\text{CHROMA}}$. Thus, 7.5R $\frac{5.0}{12}$ indicates Hue = 7.5 Red, Value = 5.0, and Chroma = 12. The Munsell System is published in book form for convenient reference and constitutes an atlas of color containing about 1,000 color samples.

The ICI System of Colorimetry

The purpose of the ICI system is to establish a fundamental numerical basis for color specification. Referring again to Figure 1, we see that the color of the modulator depends on three principal factors:

- the spectral distribution of the source of light
- the object's spectral reflectance or transmittance
- the color response of the observer

The first and last of the above factors had to be standardized by international agreement if a universal system of color specification was to result. The International Commission on Illumination (ICI) did this in 1931 by establishing three light sources and the response of a standard or average observer. The sources were arbitrarily named Illuminants *A*, *B*, and *C*, and were specified to simulate three common sources. Illuminant *A* provides an energy distribution corresponding to that of incandescent light (black body) operating at 2,854 deg Kelvin. Illuminant *B* provides a distribution similar to noon sunlight. And Illuminant *C* provides a distribution corresponding to average daylight. The spectral distributions for the three illuminants are shown in Figure 2a.

It has been brought out in this article that individuals differ in their color judgment even when their color response is considered normal. Because of this a method that would avoid the uncertainties of individual judgment had to be found. The method adopted was to substitute a set of response curves that corresponded to the average of a number of "normal" observers. These curves then became an "average" or "standard" observer. Figure 5 shows these curves and their meaning is explained schematically by reference to Figure 6.

Consider Figure 6 and let us imagine a divided photometric field, *F*, the two halves of which can be illuminated independently. Assume that the left half is illuminated by a mixture of three primary colors originating at three sources, labeled E_x, E_y, and E_z. For convenience, we can think of these sources as emitting red, green, and blue light. Assume also that the intensity of each of these primaries can be controlled independently by some means, such as a graded gray filter or wedge in front of each source.

Now suppose that a pure spectrum color of narrow band-width is introduced into the right half of the field, *F*, in Figure 6. This is represented schematically by means of an equal energy source, E_e, and a prism to disperse the light into a spectrum. The intensities of the three primaries are now adjusted until the two halves of the field match in color. The settings on the intensity controls of the primaries are recorded and the process is repeated until the entire spectrum has been traversed.

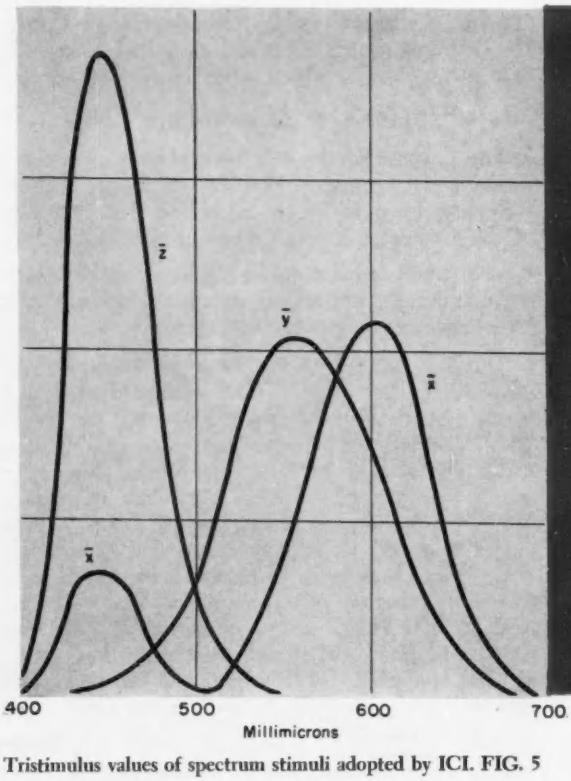
The above procedure is duplicated with a number of carefully selected observers and the results are averaged: Figure 5 shows this average. These curves represent the amounts of each primary stimulus required to match spectrum light at each wavelength. Thus, in order to match spectral light of 578 millimicrons it will require equal intensities of Sources E_x and E_y and zero of E_z.

Convert to Chromaticity Coordinates

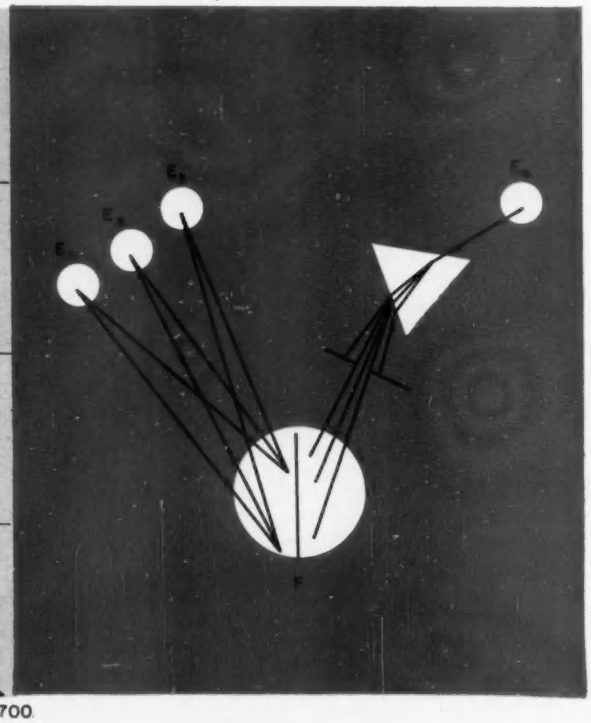
A more useful form is obtained if the tristimulus values of the spectral colors are converted to chromaticity coordinates by the following ratios:

$$x = \frac{x}{x+y+z} : y = \frac{y}{x+y+z} : z = \frac{z}{x+y+z}$$

Obviously, $x + y + z = 1$, so any two of these are sufficient to define a locus of the spectrum colors. The most commonly chosen are x and y, and Figure 7 shows the spectrum locus plotted in these coordinates. The horseshoe boundary shows the spectrum colors starting with 400 millimicrons at the lower left corner to 700 at the lower right. All real colors lie within the boundaries of the horse shoe and a straight line closing its open end.

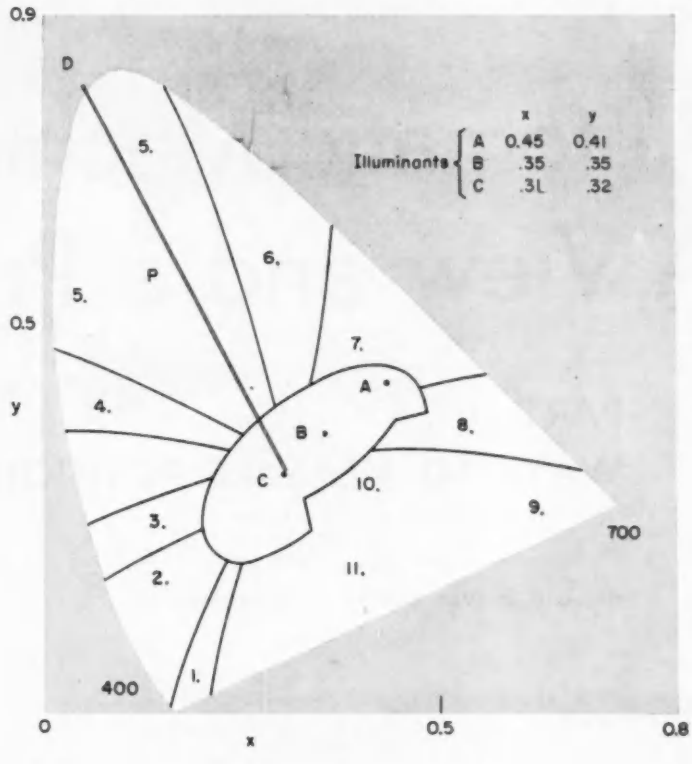


Tristimulus values of spectrum stimuli adopted by ICI. FIG. 5



Schematic photometer for obtaining data for Fig. 5. FIG. 6

1. Violet
2. Blue
3. Green-blue
4. Blue-green
5. Green
6. Yellow-green
7. Yellow
8. Orange
9. Red
10. Pink
11. Purple



ICI Chromaticity diagram, *x*-*y* plane.
FIG. 7

Figure 7 is called a chromaticity diagram. It is often helpful to plot colors of objects on this diagram. To do this it is necessary to evaluate the following integrals:

$$X = \int ERx\, d\lambda : \quad Y = \int ERy\, d\lambda : \quad Z = \int ERz\, d\lambda$$

in which E represents the spectral distribution of the source of illumination, R the spectral reflectance (or transmittance) of the colored object, x, y, and z the tristimulus values of the spectral colors, and X, Y, and Z the tristimulus values of the colored object under the given illuminant.

The above integrals, therefore, take into account the source, modulator, and detector shown in Figure 1. All the factors within the integrals are functions of wavelength, but unfortunately, do not lend themselves to simple mathematical expression. The integrations, therefore, must be performed graphically or mechanically. More will be said about this in Part 2 of this article, which deals with instruments for color measurement.

For the present let us assume we have performed the integrations and obtained the tristimulus values, X, Y, and Z, for a particular body color. The chromaticity coordinates for plotting this color on the chromaticity diagram are obtained in the same way as with the spectrum colors; namely,

$$x = \frac{X}{X+Y+Z} : y = \frac{Y}{X+Y+Z} : z = \frac{Z}{X+Y+Z}$$

Using exactly the same procedure, the color of a source can also be plotted on the chromaticity diagram. Figure 7 shows ICI Illuminants A, B, and C plotted in this way.

The chromaticity coordinates, x and y, and the tristimulus value, Y, define a color uniquely. Y is called the luminous reflectance and is a measure of the lightness of a color. The reason for this designation is that the y curve of Figure 5 was chosen to correspond to the eye response curve.

Although x, y and Y constitute a unique specification of a color, they possess no psychological significance. A more familiar terminology results if a straight line is drawn from the Illuminant point, C, through the color point, P, and extended to intersect the spectrum locus at D. The wavelength corresponding to the intersection point is called the dominant wavelength and the ratio of CP to CD is called the spectral purity of the color plotted at P. Then the specification of a color is—dominant wave length, spectral purity, and luminous reflectance (Y).

The table below relates the various terms:

Psychological	*Munsell*	*ICI*
Hue	Hue	Dominant Wavelength
Lightness	Value	Luminous Reflectance (Y)
Saturation	Chroma	Spectral Purity

The related terms are simply different names for similar concepts, but are not synonymous.

Automatic Machining— A View and a Preview

PART II: WAYS TO MEASURE POSITION AND SIZE

WALDO H. KLIEVER, Clevite-Brush Development Co.

THE GIST: A programmed machine tool control system must perform three functions. First the machine must be instructed, then it must position the tool or workpiece in accordance with these instructions, and finally it must measure to make sure that the instructions are carried out. Last month's CONTROL ENGINEERING covered ways to instruct and ways to drive. This article deals with ways to measure.

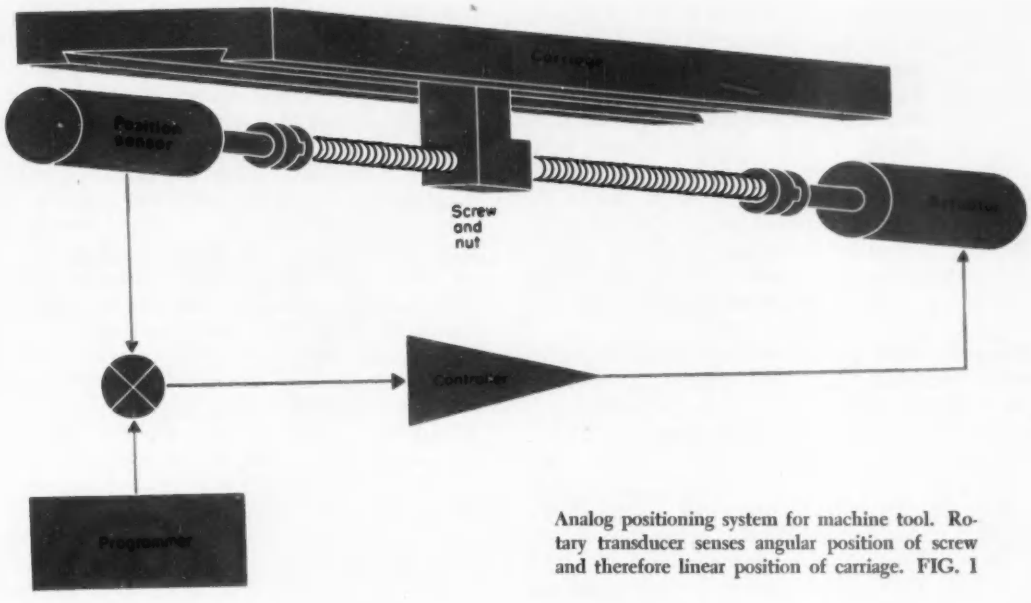
Many common analog position transducers and several new digital techniques can be used to measure tool or workpiece position. But measuring position doesn't necessarily mean that the workpiece will be machined to the correct size and shape. Thus, some consideration is also given to the problem of continuously gaging workpiece size.

An actuator normally moves a carriage carrying the tool or the workpiece only in accordance with signals received from a controller. To generate these signals the controller must compare the actual position of the carriage, or the size of workpiece with that specified by the instructions to the machine. Thus the basic accuracy of a machine depends on the ability to produce a signal that is an accurate measure of position or size. Many common position transducers can be used for this purpose. In general, these are restricted to those devices that will give a usable signal over a considerable range of linear or rotary motion since this characteristic is important in machine tool control systems.

The most desirable quantity to measure is the actual dimension of the part being produced since this eliminates the errors that are introduced by tool wear and other variables. While some steps have been made in this direction (see next month's section on Automatic Gaging), most machine tool control systems measure and control the position of the carriage that carries the tool or workpiece, Figure 1. Machining errors can be corrected at periodic intervals by manually inspecting sample pieces and adjusting the control system.

The most important factor in measuring carriage position is accuracy. While in many control systems accuracies of two or three per cent are satisfactory, it may be necessary to position a milling machine carriage to within 0.0001 in., where the total travel of the carriage is 100 in. This represents an accuracy of one part in a million of the total range.

One general means to obtain this accuracy is to measure position with a combination of a precise



Analog positioning system for machine tool. Rotary transducer senses angular position of screw and therefore linear position of carriage. FIG. 1

mechanical transmission device and a repeating transducer. Typical is a mechanical screw and a rotary transducer. If an accurately machined screw has ten threads per inch, then the transducer need only measure the angular position of this screw to $\frac{1}{3}$ deg to give an accuracy of 0.0001 in. To completely specify position, the turns of the screw must also be counted. But in some systems, it can be assumed that if the tool and the work are started in the right relative positions, this relative position will be maintained without counting and feeding back the number of turns.

Sometimes a single transmission device such as a screw is used to drive the machine and also as a measuring device, but this results in possible disadvantages. Accuracy will suffer due to wear and distortion from the applied forces. If the carriage is driven by some other means, such as a hydraulic cylinder, then the screw will not follow since it is not normally a reversible device unless driven by additional servo motors and sensing devices. If instead, the rotary transducers are connected to a pinion and driven by a toothed rack, the system can be used for measuring only and will follow the motion of the carriage without distortion. The rack and pinion principle can also be used for driving the carriage, but again, it is preferable to drive with one rack and measure with another.

Linear position measurement can be accomplished directly by using inherently linear transducers, such as the linear synchros, linear motion potentiometers and the various digital techniques. Using these devices, position is usually measured directly without the mechanical advantage of such things as racks and screws, and the accuracy of positioning depends directly on the accuracy of the transducer.

Similar methods are encountered in the angular positioning of rotary carriages. A rotary transducer can be used directly, or through spur gearing or a worm and worm gear. A worm is analogous to a screw and will not normally overhaul.

The available transducers for measuring carriage position can be divided into analog and digital devices. Each has its place, depending on speed, accuracy and the complexity of the workpiece. Actually, overlapping of analog and digital techniques often exists. For example, a screw with a synchro uses analog methods to measure the fraction of a turn of the screw, and may use digital methods to count the complete turns.

ANALOG WAYS TO MEASURE POSITION

An electrical position transducer generates a signal that is a function of mechanical position. This signal is compared with a similar signal representing desired carriage position and the difference is amplified and operated on and used to drive the actuator to reduce this difference. The important thing is that the command signal indicating desired position must have electrical characteristics that are similar to those of the signal indicating actual position. For example, in a control with synchro feedback, the signal from the memory or computer must look like that from a synchro transmitter.

If the command signal comes from a template or

master in a programmed profiler, it can be directly produced by a matched transducer. If it comes from a recorded memory such as a magnetic tape, the record may be made by recording a transducer output, or the command may be completely synthesized as by a computer. The transducers discussed below are often considered in pairs, a transmitter and a receiver, and the electrical information passing between them can be recorded or telemetered or the transmitter output can be entirely simulated.

With these points in mind, the following briefly discusses some of the common types of analog position transducers. Note that resistive, inductive, and capacitive devices are included along with combinations of these variables.

A standard rotary synchro is an induction type component consisting of a three-phase Y-connected stator and a single phase rotor. These units develop an output error voltage proportional to the misalignment between the shaft of the receiving component (control transformer) and the shaft of the transmitting component. Synchros are available that will measure to 20 min of arc, and special units are accurate to 1 min. As mentioned previously, a 20-min synchro with a 1/10-pitch screw will give an accuracy of about 0.0001 in.

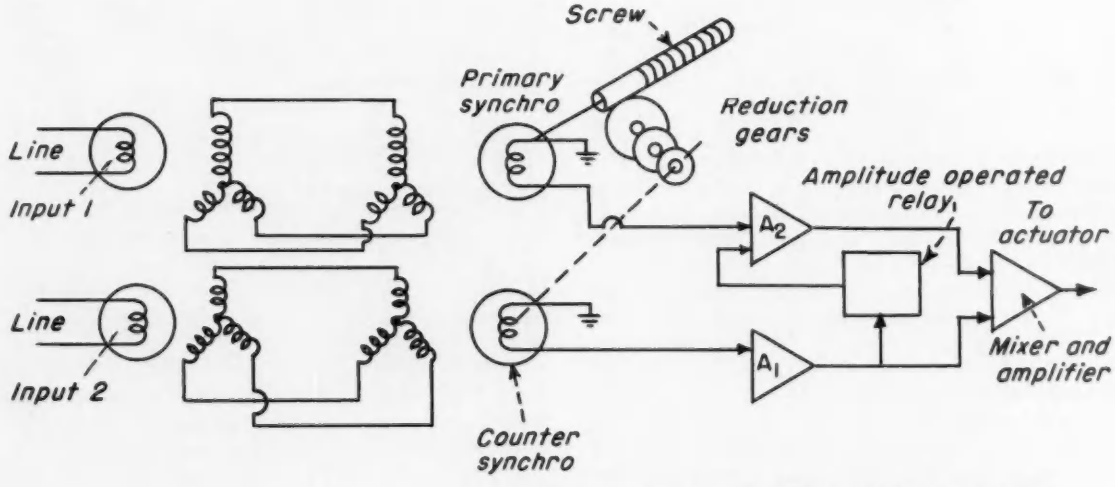
Screw turns can be counted by using a second synchro which is geared so that one complete traverse of the carriage represents one revolution. For example, if this synchro also has an accuracy of 20-min, it is possible to distinguish turns over a travel of 3 to 4 feet. Figure 2 shows a schematic of this system when the input signal corresponding to desired position contains separate data about the number of turns and the fraction of a revolution.

In this system a switching device gives control to the turn counter until the screw is within ½ deg of correspondence, at which time control is switched over to the fractional revolution synchro. This can be accomplished by controlling the gain of the position amplifier with a bias voltage from the turn counting amplifier. Thus the gain of the position amplifier is reduced to a low value when the carriage is more than ½ turn from correspondence. As the carriage approaches the desired position, the output of the turn counting amplifier becomes very small, thereby removing the limiting bias from the position synchros. Then these assume control and precisely position the carriage.

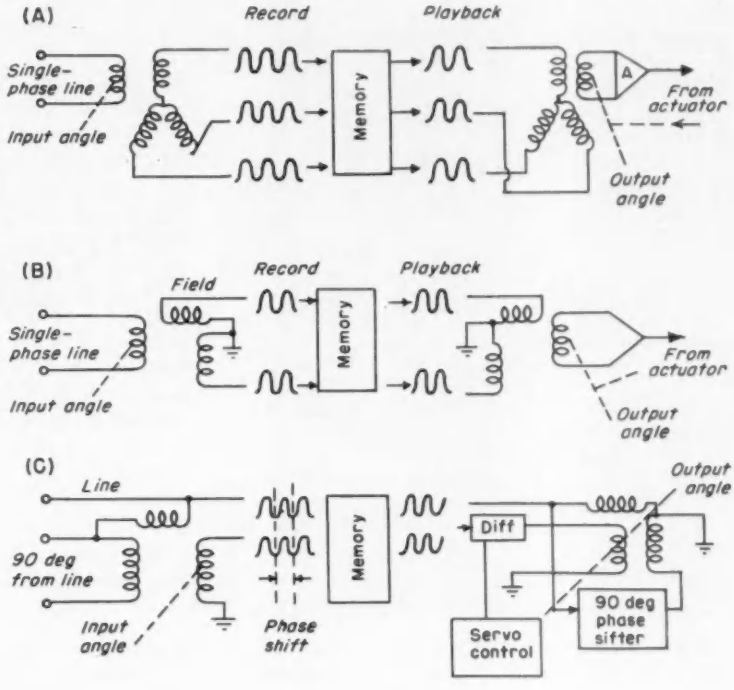
Figures 3A and 3B show a three-phase and a two-phase synchro as they would be used in record-playback systems. In each case the output of the transmitter is recorded in a memory device so that the output of the memory can be used to supply the desired command signal to the receiving synchro. The signals from the transmitting synchros are amplitude modulated, but can be converted to frequency or other form of modulation for recording purposes. The phase shift system, Figure 3C, operates on only one record channel for each control axis, plus a common reference channel.

The synchro principle can also be used in the linear form as shown in Figure 4. The two- or three-phase unit shown in Figure 4A requires accurately machined pole faces and precise guidance, but responds rapidly if the carrier frequency is sufficiently high. Linear synchros such as these are commercially available; for instance, the Inductosyn.

There are a variety of other variable transformer magnetic sensing devices that can be used for meas-



Two-step synchro system used for positioning screw. Counter synchro indicates the number of complete turns while the primary synchro indicates the fractional turns. FIG. 2



Three-phase (A) and two-phase (B) synchros used in record-playback system. Position is recorded in memory channels as amplitude modulated signals. (C) shows phase shift recording system. FIG. 3

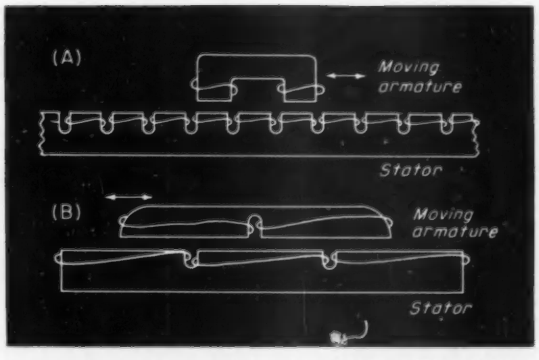
uring position. These include the Magnesyn, Synchrotel, saturable-core or flux-gate types with rotary permanent magnets, the E-magnet and all of its variations (such as the Microsyn) and linear differential transformers. Most of these devices are used only for zeroing devices or limit functions because of their limited range. Figure 5 shows schematics of a typical E-magnet and a Microsyn.

Turning from the inductive types, resistive potentiometers represent a widely used type of position transducer because of their accuracy, inherent linearity, and relative freedom from ac distortion and phase shift. They are used in a variety of forms, both rotary and linear, and sometimes in combination with inductive or capacitive transducers.

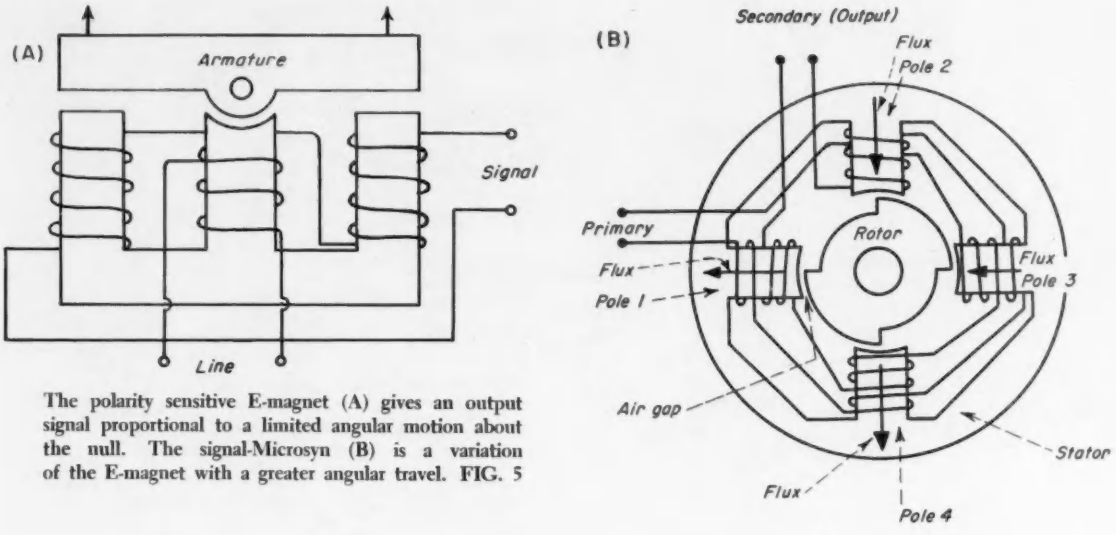
Resistance potentiometers generate a signal proportional to the product of input voltage and the linear or angular motion. The accuracy of quality potentiometers ranges from 0.1 to 0.01 per cent of their total range. Any application must consider the problems of wear of the wiper and the windings, and the effect of steps in the output which result as the wiper passes over the turns.

The ac potentiometer bridge circuit shown in Figure 6A can use either linear motion or rotary potentiometers. It will also work in dc control systems if a floating dc supply is used instead of the transformer. However, single-turn rotary potentiometers find limited application in machine tool control systems since the percentage accuracy over the available ranges is usually inadequate. Multiple-turn helical rotary potentiometers are better since they are available in up to 40 turn models.

Tapped continuous potentiometers can be used in the rotary arrangement shown in Figure 6B. They will operate on either ac or dc. This circuit is similar to a synchro system in that it repeats itself every revolution. When used with a precision mechanical transmission, such as a screw, high accuracy can be obtained.



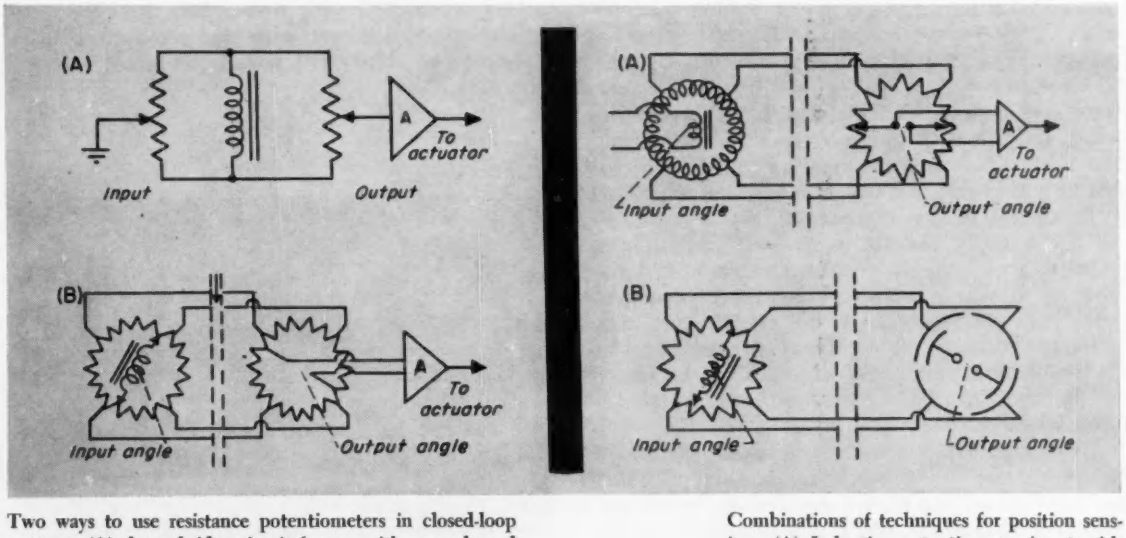
Two- or three-phase field (A) and single-phase field (B) linear synchros. Output of multi-phase unit is repeated phase shift, while output of single-phase unit varies in amplitude. FIG. 4



The polarity sensitive E-magnet (A) gives an output signal proportional to a limited angular motion about the null. The signal-Microsyn (B) is a variation of the E-magnet with a greater angular travel. FIG. 5

Both linear motion and rotary potentiometers are available in many different types of construction. Basic selection factors include linearity between angular position and output signal, resolution error, reliability, temperature stability, and the ability to withstand vibration without excessive contact bounce.

In some applications it is possible to use combinations of the above sensing devices; for example, a synchro for screw position and a linear potentiometer for turn counting. Figure 7 shows combinations of tapped continuous rotary potentiometers with inductive and capacitive elements. These will work only on ac and can be used in a manner similar to that of the rotary resistance potentiometers in Figure 6B. The dotted lines in Figures 6B, 7A, and 7B indicate the point at which signals are

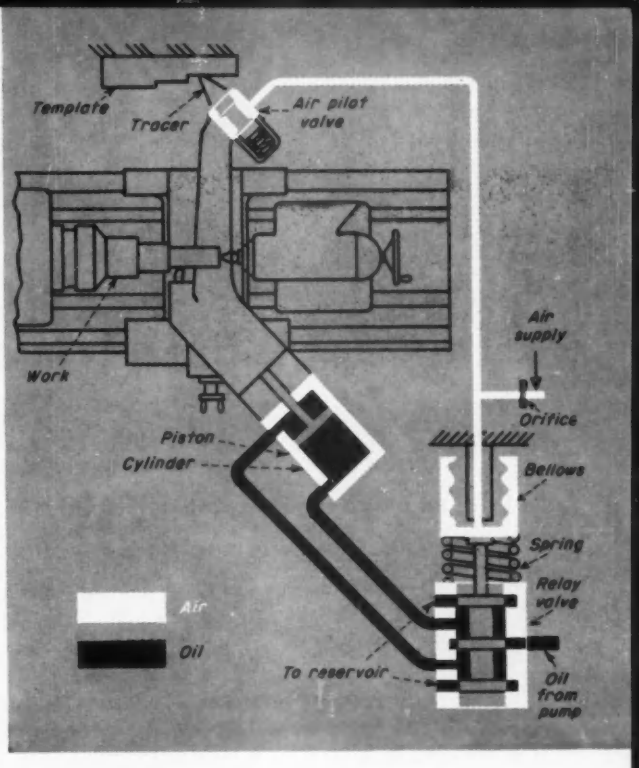


Two ways to use resistance potentiometers in closed-loop systems. (A) shows bridge circuit for use with ac or dc and either rotary or linear motion pots. (B) shows continuous rotary follow-up system with tapped rotary pots. Dotted lines shows point of possible record-playback. FIG. 6

Combinations of techniques for position sensing. (A) Inductive potentiometer input with resistance potentiometer output. (B) Resistance potentiometer input and capacitive output. Both systems for ac only. FIG. 7

recorded and played back if the circuits are used in this type of system.

Although most position measuring devices give an electrical output signal, other types are available; for example, the pneumatic sensor shown in Figure 8. In this application the position of the carriage, with the pilot valve mounted on it, represents actual position, while the tracer shape represents desired position. The air sensor is a comparator and delivers a pressure proportional to the difference between desired and actual position. This is amplified hydraulically and drives the carriage to the correct position. This could be accomplished in a similar manner with direct hydraulic sensing or by using one of the limited motion electrical position transducers. These techniques have limited applications since they can only be programmed by a mechanical template or cam.



Lathe with tracer attachment. Pneumatic sensing device develops a signal proportional to difference between desired and actual position. Monarch Machine Tool Co. FIG. 8

SOME BACKGROUND READING

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12. *SERVO CONTROLS AS APPLIED TO VARIABLE DISPLACEMENT PUMPS*, J. W. Broome, National Conference on Industrial Hydraulics, 1954.
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15. *MECHANICAL TYPES OF VARIABLE SPEED DRIVES*, "Electrical Manufacturing," August 1952.
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19. *MEASURE MOTION to 0.0001 IN.*, "Control Engineering," pp. 50-52, April 1955.
20. *AUTOMATIC SIZING APPLIED TO PLAIN GRINDERS*, "American Machinist," pp. 93-100, Dec. 1, 1949.

Mr. Kliever will bring this part of his study of automatic machining – ways to measure and size – to a conclusion next month in the third and final article in this series.

This Computer Trims Ships

A tiny analog computer solves a static problem with many variables. Nautical application should suggest many other earthy uses for simple special purpose computers.

LENNART SWENSON and BENGT BENGTSON,
Gotaverken Shipyards, Gothenburg, Sweden

Panels of the Analog. FIG. 1

The longitudinal moment of flexure in a ship theoretically is made up of hydrostatic moments and moments from load, bunkers, and construction weight. The resulting moments in hogging and sagging (Figure 2) depend on the difference between these other moments. Distributing the ship's cargo properly makes the hogging and sagging moments equally large. This load distribution is called the ideal moment, and any deviation from it means that one of the moments becomes larger than the other.

According to the simplest rules of bending, the ideal moment should give only nominal stresses on the lengthwise stringers in the ship's section. Determining whether the highest possible safety factors have thereby been reached, however, is complicated. It depends on such points of construction as the position of the neutral axis, possible differences in degree of tension stresses and compression stresses, differences between concentrations of stresses in decks and bottom, buckling strength of various joints, differences in strengths of the materials, etc. Experience so far has shown, however, that it is advisable to load the ship as close as possible to the ideal moment.

A well executed load distribution, (a poor one is where no regard is taken to stresses in the hull) can mean a reduction of 20 per cent in longitudinal stresses. Normally, strengthening the decks and bottom to compensate for such a moment brings a 6 to 8 per cent increase in material cross section. The result in a 17-to-18,000-ton tanker is a weight increase of 100 tons and a corresponding decrease in payload. This represents for a newly built ship a $20,000 rise in cost; and for an older ship that is strengthened, a considerably higher price. This gives a good picture of the importance of load distribution.

The problem then is to prevent unnecessary strain from improper load distribution. Götaverken's "Lodicator" is a solution that has been adopted in more than 100 ships. Experience with it has been very good.

A LOADING ANALOG

The longitudinal moment of flexure reaches its greatest value approximately at the ship's longitudinal midpoint. It is composed of two opposing terms: the load moment in one direction and the moment of hydrostatic forces in the other.

The Lodicator analogs these moments and measures the difference between them in an electric bridge network. By coupling in various ways this electric system can also show the trimming moment, i.e., the difference between fore and aft moments.

The instrument is portable and has two panels as seen in Figure 1. The "load panel" hangs vertically, while the "reading panel" rests horizontally when in use. The load panel has one knob, graduated in tons, for every cargo hold in the ship.

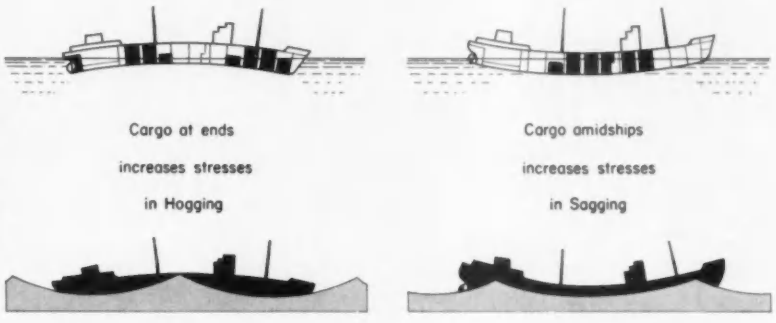
To facilitate the distribution work a profile and plan of the ship and a table of the capacities of all the ship's holds are engraved on the panels. Every knob is set to the load tentatively desired for each hold. The main selector switch, at the right on the reading panel, is then set to the "Deadweight" position. The galvanometer at the left is adjusted to zero by turning the two "Deadweight" knobs, one for coarse adjustments and the other for fine. The sum of the readings on these two knobs gives the ship's deadweight at the occasion in question.

The main switch then is turned to "Trim". Again the galvanometer must be zeroed by turning the knob marked "Trim". The scale on the knob gives the trim, i.e., the difference between fore and aft draughts, and shows whether the trim is "by stem" or "by stern". The final fore and aft draughts are obtained by respectively adding and subtracting half the trim to that average draught corresponding to the deadweight reading.

Finally, the main switch is set to "Stress". The galvanometer must again be zeroed, this time with the lower "Stress" knob. This knob's scale

The Problem:

Stresses in decks and bottoms of ships are increased by improper loading. The problem is to design a load—with ship structure in mind—to minimize the strains during a voyage. Fig. 2



The Solution:

Knobs on the electric analog of the ship's hold system, when balanced, indicate simply whether the loading is a safe one. Fig. 3

shows how favorable the load distribution is in respect to the longitudinal tensions that burden decks and bottom. (See Figure 3.)

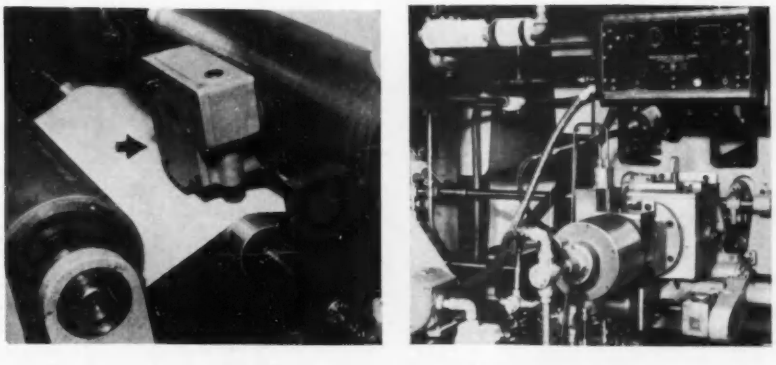
If the first distribution proves unfavorable, there is another table on the panel that works toward a more favorable distribution.

Initial condition		
Trim	Stress	Shift cargo:
By stem	Hogging	From forward to midships
By stem	Sagging	From midships aft
By stem	0	From forward aft
By stern	Hogging	From aft to midships
By stern	Sagging	From midships forward
By stern	0	From aft forward
0	Hogging	From forward and aft to midships
0	Sagging	From midships forward and aft

The big advantage in using the Lodicator is that a certain distribution can be judged before the loading begins. The load officer can make a complete load calculation within five minutes and can get information on draught, trim, stress, and stability for the chosen load plan with only one setting of the load on the load panel. Normally, it takes about two hours to calculate load distribution for a tanker. Correctness of the load setting can be controlled on the panel the whole time, and the load can be rearranged on the panel for the most favorable trim, stress, and stability readings

Although each instrument must be tailored to its ship, there are no installation costs. The only movable mechanical parts are potentiometers, switches, and a galvanometer. No electronic tubes are used. The Lodicator is powered by a 5-v storage battery that lasts about a year and is rechargeable.

A special adaptation, called the Sta-Lodicator, gives the initial stability expressed in GM, i. e., the distance between center of gravity G and the cross-ships metacenter M. Free liquid surfaces in tanks reduce GM, and this reduction is accounted for in the instrument's result. Every tank on the ship has a switch on the reading panel. If there is a free surface in a tank, the switch is set to "Free Surface". If the tank is empty or completely filled, the switch is opened.

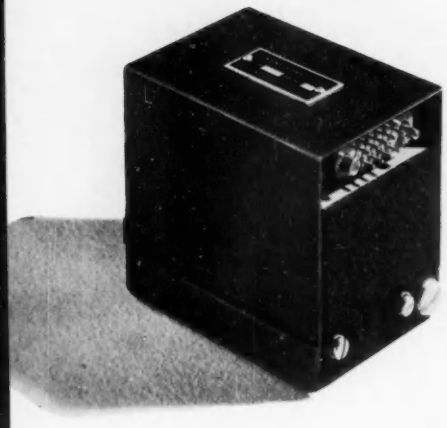


CONTROL ASSURES PRINTING BULL's EYE EVERY TIME

The photoelectric web scanner (left) and the phase detector and control instrument (right) are the main components in a system for web registration control developed by the Champlain Co. of Bloomfield, N. J. The phase detector measures the angular position of printing cylinder relative to web using coincidental wave generation. A variation more than 0.0025 in. causes control to advance or retard the cylinder.

Tap the Transducer to Up System Accuracy

When a system is not as accurate as its initial transducer, this simple idea might improve it. The application here is in a pressure telemetering system.



A specially-tapped pressure-operated potentiometer. Taps are brought out to a special plug; instrument is hermetically sealed. FIG. 1

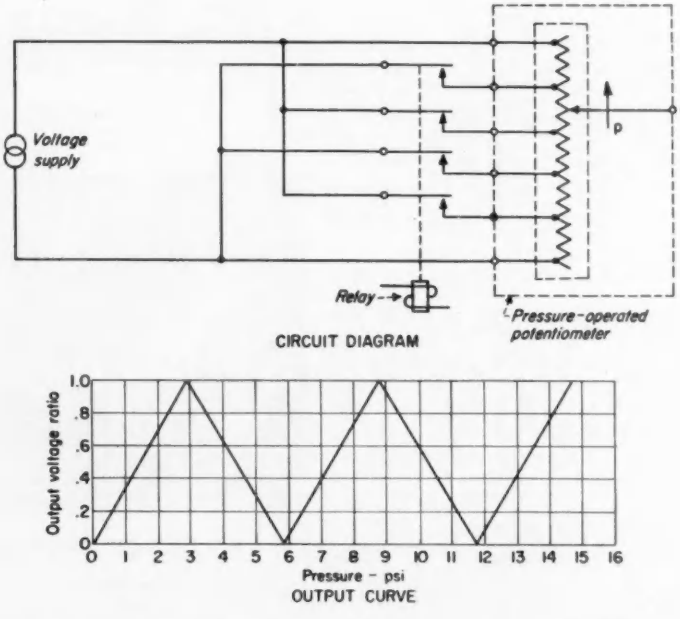
ALAN D. MAIER, Trans-Sonics, Inc.

Pressure-operated potentiometers can be highly accurate, ruggedized units, capable of meeting severe environmental requirements. In some applications, however, their inherent accuracy is partially nullified by inaccuracies in recording or telemetering equipment. Typically, the potentiometer pressure pickup may have an overall accuracy of plus or minus one per cent while the accuracy of the associated equipment is likely to be of the order of plus or minus five per cent. The problem, then, is to find a way to improve the overall accuracy of a system to take advantage of the accurate transducer.

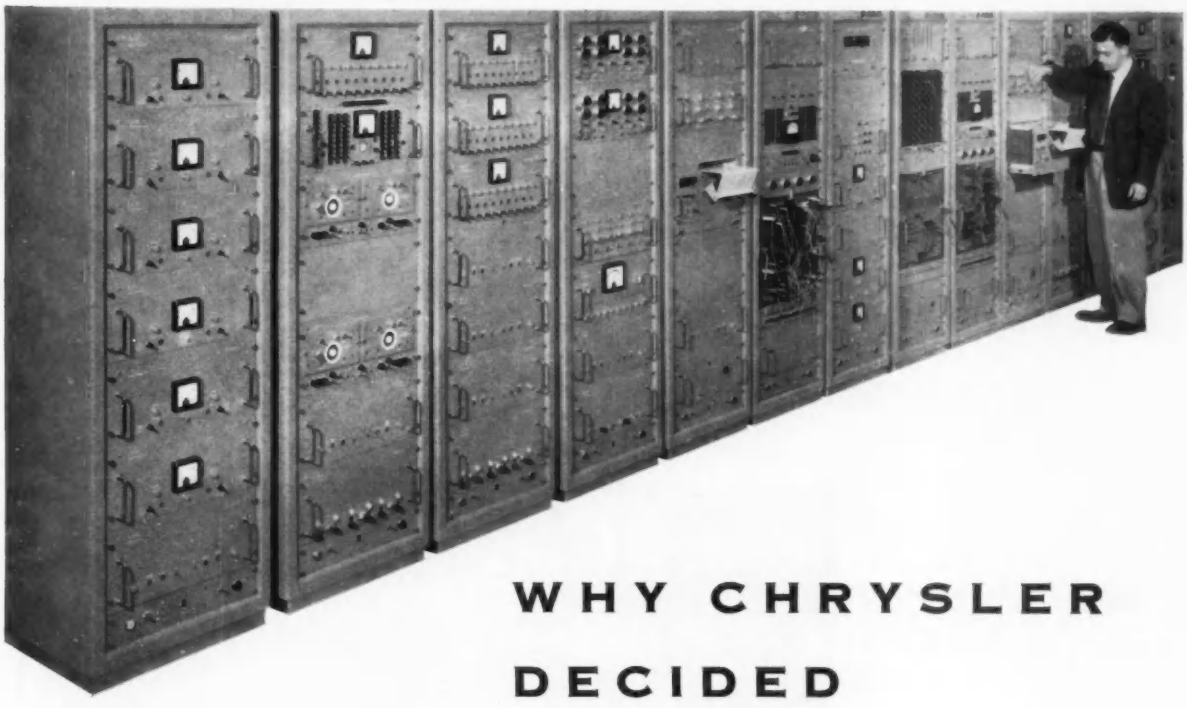
One technique that solves this problem makes use of a potentiometer pressure transducer with a multiple-tapped coil. A typical instrument of this type is shown in Figure 1. Each tap of the potentiometer winding is brought out to a terminal board mounted inside the instrument case but external to the hermetically-sealed mechanism. This construction retains the advantages of an evacuated mechanism while allowing a wide variety of interconnections between taps.

The circuit used with the tapped potentiometer is shown in Figure 2. The power supply is connected across the potentiometer winding, and to alternate taps on the winding when the relay is closed. When so connected, the output varies between zero and the maximum applied voltage five times over the range of the instrument. The recorder or indicator then moves back and forth over its full scale range five times for the full scale range of the pressure-operated potentiometer. Thus recorder or indicator errors, such as uncertainties in reading the record, paper shrinkage, drift, and telemetering errors, are divided by five.

In this arrangement any given voltage output may represent five different pressures. The relay therefore is included in the circuit to provide a positive reading of rough pressure information. When the relay is open, the instrument operates as an ordinary linear pressure transducer whose output voltage ratio varies from 0 to 1 over its full scale range. A reading taken with the relay open establishes which of the five straight line curves is in operation. In one telemetering application, this is done by opening the relay for 1 sec twice every minute.



Simple circuit makes the system as accurate as the precision transducer. Full range of the system covers fraction of the pickup's range. FIG. 2



WHY CHRYSLER DECIDED TO "DO IT WITH EASE*"

Chrysler Corporation's guided missile research engineers wanted more than the ordinary analog computer's savings in solution time. They wanted faster set-up; rapid, simple computer programming and operation; automatic data recording, and high accuracy.

Chrysler and BERKELEY engineers worked together to develop an EASE* computer matched to Chrysler requirements and offering these outstanding features:

1. *Automatic pushbutton setting of diode function generators, which permits set-up of their 12 non-linear functions in a matter of minutes rather than hours, and provides high accuracy with drift-free representation of the required function.*

2. *Automatic "hold" of computation at any two pre-set times, by means of an elapsed time clock and pre-set hold circuitry.*

3. *Digital display and readout of any selected variable on printed tape at the rate of one per second, to an accuracy of 1 part in 10,000.*

4. *Timing matrix which provides signals at any time "t" between 1 and 999 seconds, for programming control.*

5. *Remote operation and automatic scale factor indication of the recorder, controlled by the computer.*

This is an excellent example of BERKELEY's ability to work closely with customers to develop computing and simulation equipment matched to specific requirements. Availability of BERKELEY's complete line of quality-computer components means early completion and substantial savings in costs. (Overall cost of the Chrysler EASE* computer was far lower than that of competitive equipment).

An eight-page brochure describing BERKELEY EASE* computers and components is yours for the asking; please address Dept. L10

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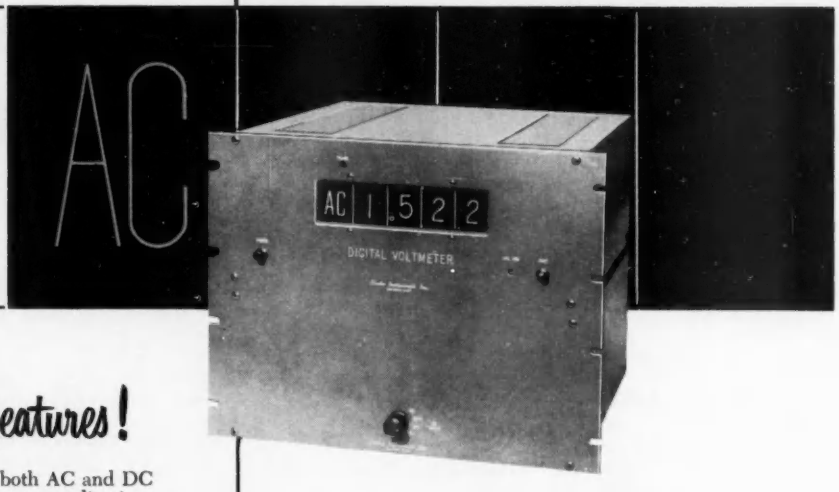


Look at these features!

Extremely versatile – Having both AC and DC in a single instrument widens your applications of digital voltmeters. Front panel switch is provided for quick selection of AC or DC.

AC accuracy 0.1% of reading, or 2 mv – Readings give true value of input wave shape with virtually zero phase shift error. Answers are then in terms of AC as used. DC accuracy ± 1 digit.

Frequency response to 5 kc with 11 megohms input impedance – Model 4500 is flat from 30 to 5,000 cycles at 11 megohms. Model 3500 is flat from 30 to 2500 cycles, also with 11 megohms. Other models to 1 megacycle with reduced accuracy and input impedance.

Range from 1 mv to 1,000 volts – EI's unique in-line read-out display indicates 4 digits from 0.001 to 999.9 volts with range indicated by decimal position. Manual range switching on AC; automatic on DC.

Reading time averages 2 seconds – On AC balance times average two seconds; on DC one second.

Quick, easy internal calibration – Front panel switch and one-point adjustment provided for instantaneous calibration. Absolute DC calibration.

Reliability – Quality components used throughout. Especially selected aged resistors assure stable, reliable life. Design techniques proved through hundreds of applications. Write for complete data.

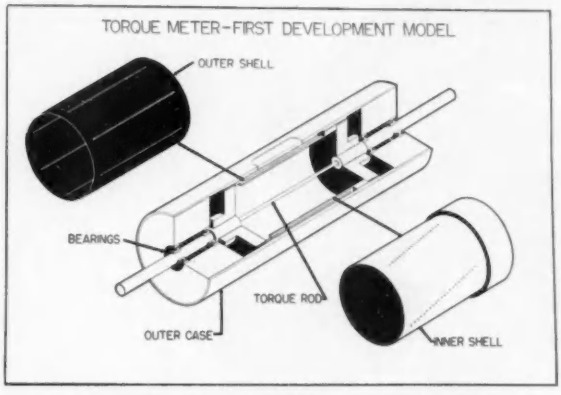
Optional features – Available for operation with printers. Read-out may be remoted if desired. Complete specifications will be sent on request.

TWO STANDARD MODELS

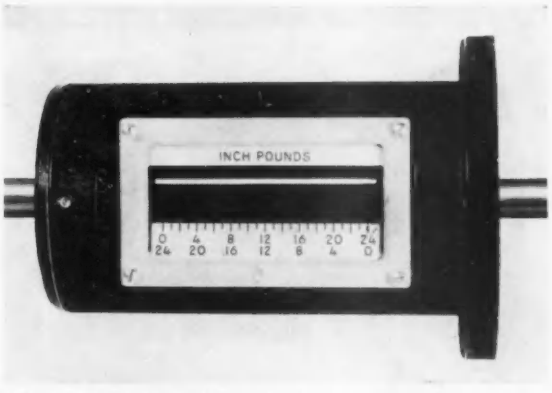
	Model 4500	Model 3500
Display	4 digits	3 digits
Accuracy	0.1% of reading or 2 mv	0.25% of full scale
Range	0.001 to 999.9 volts	0.01 to 999. volts
Frequency response	30 to 5,000 cycles	30 to 2,500 cycles
Input impedance	11 megohms	11 megohms
Range switching		
AC	manual	manual
DC	automatic	automatic
Size	14" x 19"	7" x 19"
DC blocking	400 volts	400 volts
Calibration	internal	internal

ELECTRO INSTRUMENTS INC.

3794 Rosecrans Street, San Diego 10, California



Cutaway shows simplicity of the Torquemeter. Note that outer case is bearing-mounted, need not rotate with shaft. FIG. 1



Two shells, fixed to either end of torsion spring that connects shafts, display relative displacement in this window. FIG. 2

Read Torques Directly from Rotating Shafts

A very simple instrument visually indicates torque in a stationary window. It can be read directly from standstill to 10,000 rpm or more.

IRA FRIEDMAN, Guided Missiles Div., Fairchild Engine & Airplane Corp.

The characteristics of a driven load must be known to select a prime mover. Very often torque characteristics of the load cannot be calculated because they depend upon such indeterminates as lubrication, surface friction, bearing friction, temperature and humidity, and windage. Then the nature of the load can be defined practically by measurement only.

For a known load, the torque-speed capabilities of the prime mover must also be measured to check its jog suitability and for test and inspection.

Torque can be measured either by power absorption devices, or by devices that indicate torque directly.

The power absorption devices usually are cradled dynamometers that use electrical, hydraulic, or mechanical braking methods that dissipate energy. Generally, these units measure the characteristics of the prime mover. They cannot measure reactive loads.

Direct reading torque indicators are inserted in series with the shaft whose torque is to be measured and so measure active or reactive torques. Indicators generally include an elastic torsional member and a means for reading the relative angular displacement between ends of the member.

To date, the ways to measure the relative angular displacement have been rather complex and costly. One method involves a strain gage and slip rings, brushes, power supply and an electrical indicating meter. Another employs an internal light source with a photocell and disc arrangement. The discs have a series of openings through which the light reaches the photocell. The areas of the openings vary with the relative angular displacement of the torsion spring. The photocell output is then read on an electrical meter.

USES THE EYE'S LAG

The new, direct indicating Torquemeter comprises direct visual indication of the relative angular displacement between the two ends of a torsion spring. This spring is the novel feature of the instrument. The natural persistence of vision of the eye and a calibrated pattern generate a line whose displacement varies directly (in discrete steps) with the relative angular displacement of the spring.

As illustrated in Figure 1, an inner shell with a set of helical patterns inscribed upon its surface is attached to one end of the torsion spring. An outer shell is attached to the other end of the spring and has a set of slots through which the pattern is viewed. The length of the pattern markers and width of the slots are such that one or (at the most) two markers are visible for any particular angular displacement between the inner drum and outer shell.

When the entire assembly is rotated, the exposed markers appear as lines generated about the periphery of the inner shell. The position of the lines indicates the applied torque. This position is read on a scale fixed to the instrument's outer case and calibrated in torque units. The outer case, Figure 2, does not rotate.

The spacing between divisions of the scale corresponds exactly to the longitudinal spacing between the markers on the drum. When the measured torque reading corresponds exactly to a scale division, only one line is visible at that division. When the torque reading is between two scale divisions, two lines are visible at the corresponding divisions.

MEASUREMENT ACCURACY

Reading precision depends upon the number of scale divisions. The number of discrete readings possible is twice the number of scale divisions; i.e., with 25 scale divisions, a reading precision of better than two per cent is possible. When the reading is between two scale divisions but closer to one than the other, the relative intensity of the lines indicates which division is to be favored.

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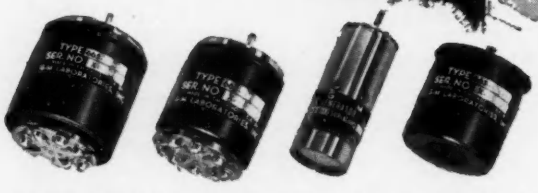

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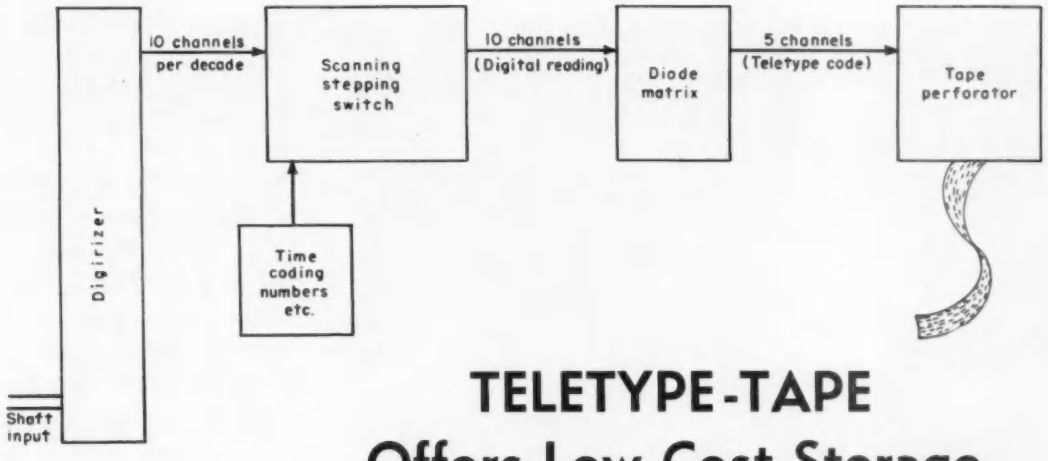


TELETYPE-TAPE Offers Low Cost Storage

HAROLD DICKSTEIN, Convair-San Diego

Teletype-tape-to-card records are attractive for storage of data to be processed by punched-card computers. The "automatic shaft position data encoder" pictured in the block diagram is an inexpensive way to make such tapes if the data-interval is more than a few seconds.

Teletype tape has certain advantages over punched cards for data storage:

- A large amount of data can be stored more compactly
- Tape is light and easy to handle; data sequence is not easily disturbed
- Data can be recorded automatically with a small, lightweight unit

Commercially available units for recording data on teletype tape are quite versatile, will record data 20 times per sec or more, but are large and electronically complicated. They are not portable and do not lend themselves to field operations. They are also expensive (in the order of $20,000). A small, lightweight unit has been developed for use where data is recorded only every 5 sec or more, and where the system can be held still for about 2 sec for each reading.

SMALL VERSION FOR SLOW DATA

The unit is designed to record on teletype tape the position of a rotating shaft within 0.1 revolution up to 1,000 revolutions. It is called an "automatic shaft position data encoder" (ASPDE). The entire unit measures 17 in. by 12 in. by 10 in. and weighs only 60 lb.

The ASPDE uses no electron tubes; it is completely electromechanical. Two commercial items are used: the "Digitizer", made by Coleman Engineering Co., and a Western Union 4804-A tape perforator. The rest of the equipment consists of relays, stepping switches, germanium diodes, and a selenium power supply.

Cams on a timing motor close a switch to initiate the shaft position reading. The cams are adjustable to permit varying of the interval between readings. This time interval was set at 6 min for the original application, but could easily be any period from a few seconds to many hours.

FIRST, CONTROLLED READING

After start by the timing motor, a stepping switch controls the reading operation. The first position on the stepping switch is permanently wired to mark the symbol for figure shift on the teletype tape. In this way any teletype equipment that uses the tape will remain in figure shift for each piece of data.

The second step connects a manual selector switch to the tape perforator via a matrix of germanium diodes. The diode matrix transforms the selector switch position into a number in the teletype's code. Thus, the operator can insert an identifying number for the data run being made.

The next three positions are similar coding arrangements for automatic recording of time or data count. The necessary equipment for these operations has not been incorporated to date.

THEN, THE SHAFT POSITION

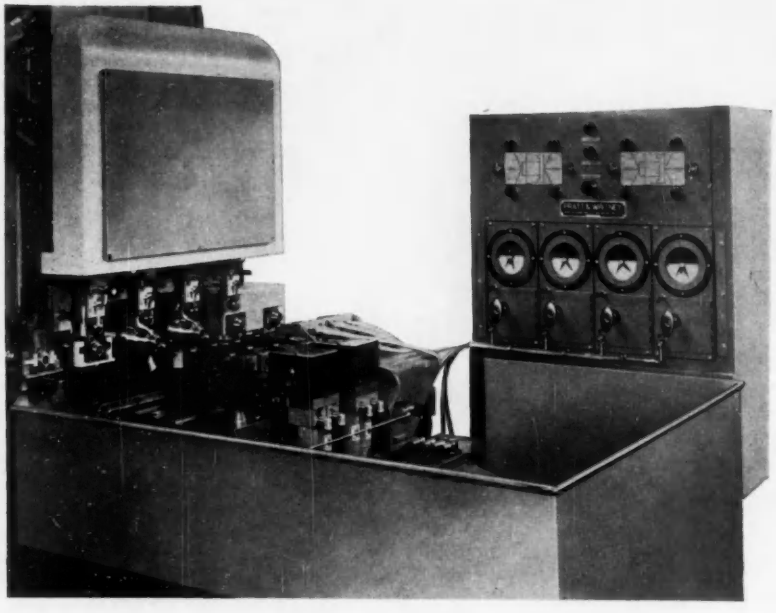
Positions 6, 7, 8, and 9 connect the output of the thousands, hundreds, tens, and units decades of the "Digitizer", in that order, to the tape perforator through the diode matrix. The diode matrix, again, changes the digitizer signal to the proper code for the teletype tape perforator.

The tenth position of the stepping switch produces a permanently-wired "line feed" symbol on the tape, and the eleventh causes the inscription of the carriage return symbol. The eleventh position is also the normal "rest" position in which the switches remain until the start of the next reading.

Two stepping switches are used to get the necessary number of banks. Pulses from the teletype punch hammers actuate the switches to insure that a reading has been recorded before stepping on to the next position.

Because the unit takes about 1 sec to record a reading, the shaft being read must be stopped for at least that long. During reading the ASPDE closes a switch, which can be used to ground the error input of the servo driving the shaft being recorded. It is also possible to bypass the timing motor and initiate readings manually.

NEW PRODUCTS



LISTING IN GROUPS

1- 6 Systems & Computers
7-18 Recorders & Indicators
19-22 Servo Elements
23-32 Some Detectors
34-36 Torque and its Transmission
37-49 Relays & Switches
50-57 Power Sources

IN-LINE gaging provides feedback to boring machine.

A new Pratt & Whitney air gage provides electrical step impulse signals to control the boring machine it is mounted on. In doing so it corrects for tool wear, indicates out-of-tolerance conditions, and stops the machine in the case of rejects.

The gage measures to 0.0003 in. maximum tolerance, although the maker claims repeatability in the range of millionths of an inch. Light signals provide out-of-tolerance warning. The back-pressure gaging system is basically the same as on all P&W Air-O-Limit gages. The accuracy of the controller stems from the use of precision pressure switches and relays. Control limits can be readily adjusted for varying tolerance requirements. The photo shows the gage applied to a New Britain-Gridley Automatic Dual Boring machine. This is how it was demonstrated at the Chicago Machine Tool Show in September.

Pratt & Whitney has also developed a numerically controlled jig borer with positional accuracy of 0.0001 in. Instructions can originate from punched cards or tape. The machine's table surface is 22 by 44 in. and maximum travel time is 15 sec.

Another new item in the company's line is a spark-gap tracer called the Velvetrace. A model to be followed is grounded and changes in voltage between the probe and the model are amplified to operate slipping clutch servos that position the spindle. *Pratt & Whitney, Miles-Bement-Pond Div., West Hartford 1, Conn.*

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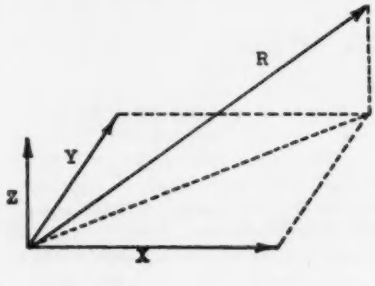
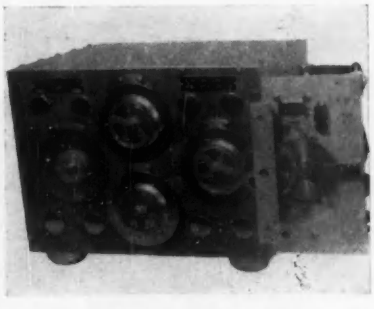
TRIANGLE SOLVER specializes in accurate spherical trig.



The diagram to the left shows the problem this computer was built to solve. Shaft inputs provide the machine with values for X, Y, and Z, whereupon it solves for R within 0.01 per cent. The output is either shaft rotation (60 oz in. torque) or analog voltage. Maximum input shaft velocity for X and Y is 1.5 rpm, with 15 turns full scale. This Slant Range Computer SRCX-1 is said to be the most accurate analog triangle solver in existence. *Julie Research Laboratories Inc., 341 E. 149th St., New York 51, N. Y.*



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for two more
digital system items

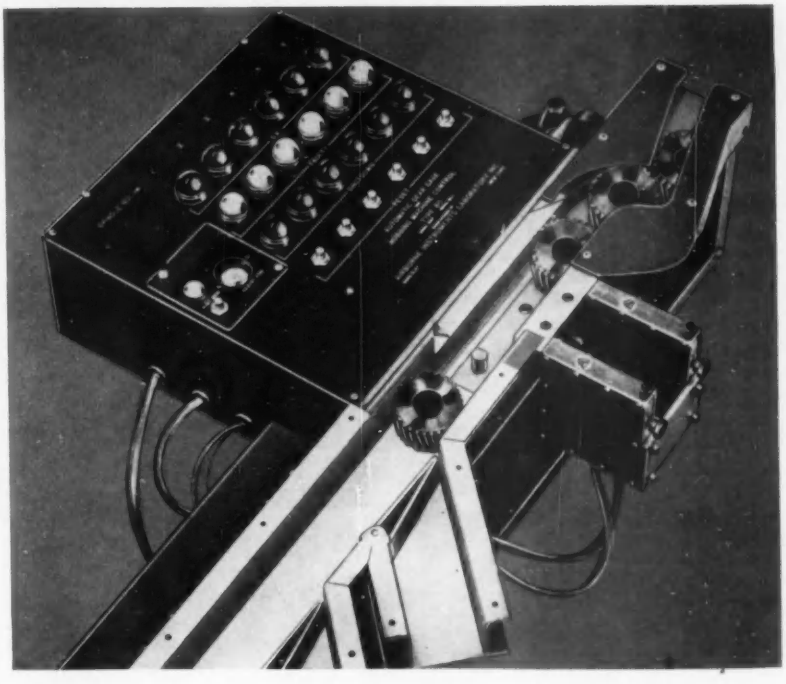
GEAR INSPECTOR provides feedback to hobbing machine.

Simple feedback signals from this gear tolerance inspector, when used with gear hobbers, produce automatic or manual adjustments of mean pitch diameter and root-fillet shape. If the adjustment is to be done manually, indicator-lights request this.

The Type 80 chutes gears at rates up to 100 an hour, according to acceptable, salvageable, and unsalvageable categories. If too many gears are made outside of tolerance limits, the gear gage will shut down the hobber.

Pitch diameter is determined by a modified ball-type measurement. Electrical signals can correct automatically. The effects of hob wear are also measured. Hob shift signals result according to actual hob wear. Previous techniques called for hob shift at predetermined intervals, based on assumptions of hob wear.

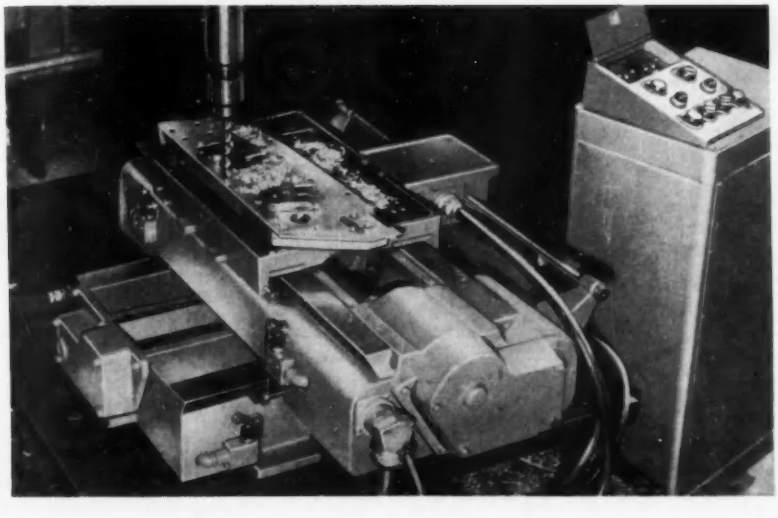
The Type 80 Automatic Gear Gage and Hobbing Machine Control is customed-designed for each application. It will operate with hobbers making gears from less than 1 in. up to several inches in diameter and any tooth type.



Tolerances are adjustable from 0.0005 in. to 0.010 in. or more, each direction from gear dimension. Its repeatability is better than 0.0001 in. *Airborne Instruments Laboratory, Inc., 160 Old Country Road, Mineola, N. Y.*

Circle No. 3 on reply card

INDENTED TAPE locates work under machine tools.



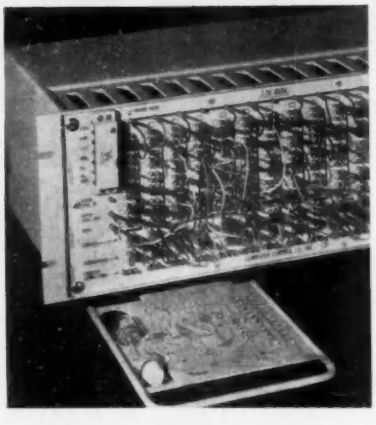
Dented steel tape provides the location information for the Micro-Positioner. Its objective is the accurate location of parts under any vertical spindle machine tool. A special marking device indents the tape according to blueprint information. The control tape can also be prepared by locating the tool over a previously marked part and using the machine's location to provide position information for the indenting process. Accuracy of three ten thousandths of an in. is claimed for the Micro-Positioner. It can be substituted for jigs or fixtures for short-run production items, says the maker. Once the tape has been properly indented, the machine can be operated from a master console, which is part of the machine. *Topp Industries, Inc., Los Angeles, Calif.*

Circle No. 4 on reply card

ACCOUNTING INFORMATION changed to punched notation.

The Systematics Intercoupler converts accounting machine data directly into punched card or tape form. National Cash Register 3100 or 3200 accounting machines can directly operate IBM card punches or 5 or 8 channel tape punches. Information punched may be data as entered on the keyboard or totals from any of the accounting machine's registers. The use of the Intercoupler does not limit the independent performance of posting machine or punch. *Systematics Inc., 105 Lyndon Dr., Hermosa Beach, Calif.*

Circle No. 5 on reply card



COMPUTER BUILDING block is digitally versatile.

The digital computer building block above can perform nearly all digital operations, including arithmetic computation, storage and programming, and logical decision, at a rate of one megacycle pulse repetition. The 3C-BLOC consists of fifteen gating packages and one synchronizing "clock" package. The operations performed by the 3C-BLOC are determined by simple plug-in jumper connections, joining the gating packages. A single block, for example, can be a shift register, adder, subtracter, multiplier, divider, function generator, code converter, storage memory, etc. The printed circuit plug-in gating package is the only spare part that need be stocked. *Computer Control Co. Inc., Wellesley 57, Mass.*

Circle No. 6 on reply card

RECORDERS AND INDICATORS

LOW RATE FLOW METER: Flows of liquids down to 0.01 gph, and air down to 0.2 are possible with the Sho-Rate "50". It takes temperatures to 250 deg F and pressures to 200 psi. *Brooks Rotameter Co., Lansdale, Pa.*

Circle No. 7 on reply card

RECORDING AIRGAGE: The combination of a Bristol recorder with a Federal airgage yields the Dimension-airs-Recorder. It can continuously record sheet or rod stock dimensions or any other measurement that can be handled by the company's variety of gaging heads. *Federal Products Corp., 1144 Eddy St., Providence 1, R. I.*

Circle No. 8 on reply card

COUNTER: The drum mounted on the input shaft of a new counter assembly is graduated into 100 units and the remaining three drums are Geneva driven to yield a total count of 50,000. Inputs to 100 rpm are okay with the 4 by 2½ by 2½ in. indicator. *Durant Mfg. Co., 1929 N. Buffum St., Milwaukee, Wis.*

Circle No. 9 on reply card

MINIATURE RECORDER mounts in panel, responds quickly.

Pen speed is 0.5 sec full scale in this null-balance potentiometer-type strip charter recorder. No standard cell or batteries are used, as standardization is automatic and continuous. Its amplifier may be mounted separately. Optional selsyn drive for the 5-in. wide chart includes a quick-change three-speed transmission. *Westronics, Inc., 3605 McCart, Fort Worth, Tex.*

Characteristics

Chart speeds	4, 10, 20 in. per hr.
Accuracy	Within 0.25 per cent
Size	8¾ by 8½ in.
Full scale input	10, 20, 50, or 100 millivolts
Power	115 vac

Circle No. 10 on reply card

NORTH AMERICAN—PIONEER AND LEADER IN GUIDED MISSILES

North American's Missile and Control Departments Offer

ELECTRONIC ENGINEERS CAREERS IN GUIDED MISSILES

NORTH AMERICAN'S MISSILE AND CONTROL DEPARTMENTS, pioneers and leaders in all phases of guided missile design and development, offer you new opportunity. Prime contractor for the NAVAHO SM-64 Intercontinental Guided Missile, North American has unusually challenging positions open for experienced electronic engineers in guidance and control developments.

Your big advantage is that you begin by drawing on the empirical data produced by North American's Missile and Control research pioneering—and you have freedom of expression while developing your own ideas. You'll use the finest equipment—work with world-recognized engineers and scientists. North American's unique engineering organizational techniques—plus our liberal Patent and Suggestion Award programs—assure you recognition and reward.

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ENGINEERING AHEAD FOR A BETTER TOMORROW

NORTH AMERICAN AVIATION, INC.

Miniature Pressure Transducers

STATHAM UNBONDED STRAIN GAGE TRANSDUCTION

MINIMUM RESPONSE TO VIBRATION OR ACCELERATION

TEMPERATURE COMPENSATION OVER 315° F. INTERVAL

20 MILLIVOLTS AT 5 VOLT EXCITATION

PRESSURE ADAPTERS FOR CLOSED LINE APPLICATIONS

HOMOGENEOUS SENSING DIAPHRAGM SURFACE

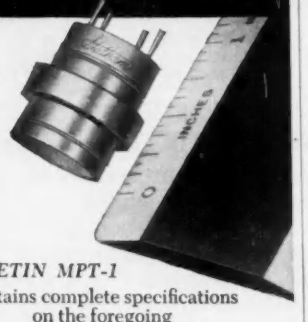
NO EPOXY RESIN PRESSURE SEALS

MAXIMUM LINEARITY

ABSOLUTE PRESSURE
0-5 to 0-150 PSIA . . . MODEL P130

DIFFERENTIAL PRESSURE
±2.5 to ±25 and 0-5 to 0-150 PSID . . . MODEL P131

GAGE PRESSURE
0-5 to 0-150 PSIG . . . MODEL P132



BULLETIN MPT-1
contains complete specifications on the foregoing pressure transducer models.

All matters pertaining to sale or use of instruments of our manufacture are handled by engineering personnel directly from our Los Angeles plant.

Please feel free to wire or telephone us collect whenever we may be of service.

Statham
LABORATORIES
12401 W. Olympic Blvd., Los Angeles 64, Calif.

NEW PRODUCTS

ANNUNCIATOR shows position information in tiny package.

A D'Arsonal type movement in the above instrument can operate on standard instrument ranges such as millivolts, milliamps, etc., to indicate position or null-balance information. It's built for aircraft use.

Another new product from the same maker is a multi-element meter that utilizes Marion Coaxial Mechanisms. It is said to be much lighter and smaller than instruments with the same weight and ruggedness. Models with up to four elements are available. *Marion Electrical Instrument Co., Manchester, N. H.*

Circle No. 11 on reply card

CONDUCTIVITY PICKUP: A new conductivity cell for measuring effluent waters is mounted in process lines just like a short length of pipe. It uses ring electrodes that are said to be self-cleaning. A thermistor can be mounted within the pipe structure for temperature compensations. *Industrial Instruments, Inc., Cedar Grove, N. J.*

Circle No. 12 on reply card

MEASURES BOUNCE to confirm press clearance.

Here is a novel use for an accelerometer. The receiving tote box or unloading mechanism for a punch press is instrumented to show the jolt that results from a received part. Unless the part is received, the press is stopped, as the un-ejected part in the machine may cause damage to the press or die when a new blank is loaded on top of it. Model PCE is for use with electric clutches, Model PCM for mechanical or pneumatic clutches. *Control Devices, Inc., 8299 E. Nine Mile Road, Van Dyke, Mich.*

Circle No. 13 on reply card

REMOTE WRITER: Letters and numerals as small as 3/32 in., positioned to within 1/64 in., are the accuracy limits of the Autron remote reproduction system. Enough pressure is applied by the ball-point pen of the receiver to make carbon copies. Twelve receivers will operate from one transmitter. The writing surface is about 5 by 2 in. *Autron Engineering, Inc., 1254 W. Sixth St., Los Angeles 15, Calif.*

Circle No. 14 on reply card

DIGITAL VOLTMETER uses digital potentiometer.

Voltages receive digital notation by a self-balancing potentiometer technique that uses oil-immersed stepping switches with a life expectancy of one million readings. Polarity indication and decimal point location are completely automatic. Luminous numerals 1 in. high give the indication. Accuracy equal to the resolution of the four-digit device is provided by nine Weston standard cells with a life exceeding 1,000 hours. Input impedance is 11 megohms. Readings at rates of 1 per sec can be made in three ranges: zero to plus or minus 9.999 vdc; plus or minus 09.99 to plus or minus 99.99 vdc; and plus or minus 099.9 vdc to plus or minus 999 vdc. Model 451 is portable and Model 451RM is for rack mounting. The power source is 115 vac. *Non-Linear Systems, Inc., Del Mar Airport, Del Mar, Calif.*

Circle No. 15 on reply card

INDICATES DEVIATIONS from reference voltage.

Nominal voltages of 100, 220, or 380 vac, or 24, 60, 110, and 220 vdc become the reference value from which the above instrument indicates voltage deviation in per cent. The measuring range is from 90 to 110 per cent of the reference voltage. This enables the reference voltage to be measured to an accuracy of 0.25 per cent. The Magnified Scale Voltmeters are made by AEG of Germany. *Donald C. Seibert, Box 281, Wilmington, Del.*

Circle No. 16 on reply card

TEMPERATURE CONTROLLER: Using resistance type temperature bulbs, the three-tube Thermotrol provides on-off, proportional or proportional plus reset signals. The proportional range adjusts from 0 to 100 per cent in nine steps. The use of reset reduces the proportional band temperature differential 100 times. Eight reset rates range from 6 to 90 sec. On-off control sensitivity is to 0.001 deg C. *Hallikainen Instruments, 1341 Seventh St., Berkeley, Calif.*

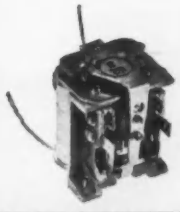
Circle No. 17 on reply card

DATA REDUCER: Ten asynchronous time interval measurements are converted into punched-card form by Epsco System No. 177. Elapsed time between pulses is measured to one tenth thousandth of a min. Dates, shaft positions identification numbers, and temperatures also are indicated. *Epsco, Inc., 588 Commonwealth Ave., Boston 15, Mass.*

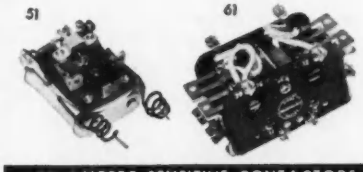
Circle No. 18 on reply card

SIGMA SENSITIVE RELAYS

HIGH SPEED RELAYS

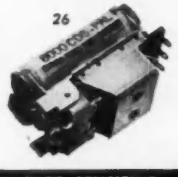


LOW COST POLAR RELAY

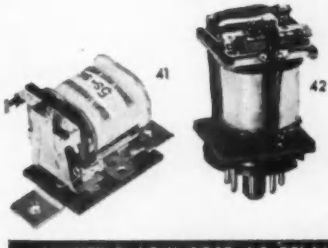


25 AMPERE SENSITIVE CONTACTORS

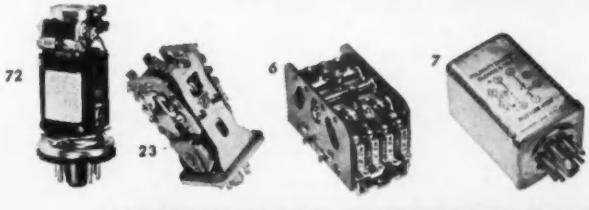
MISSILE RELAYS



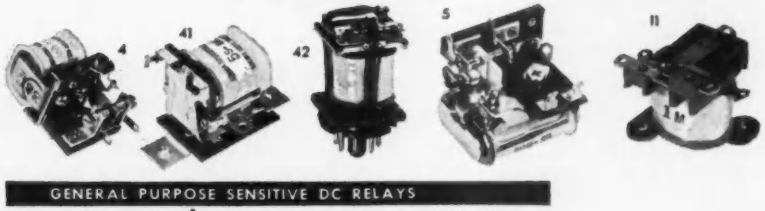
MINIATURE SENSITIVE, GENERAL PURPOSE DC RELAYS



SENSITIVE, LOW COST AC RELAYS



NULL-SEEKING RELAYS



GENERAL PURPOSE SENSITIVE DC RELAYS

complete catalog on request

Numbers indicate Sigma Relay Series

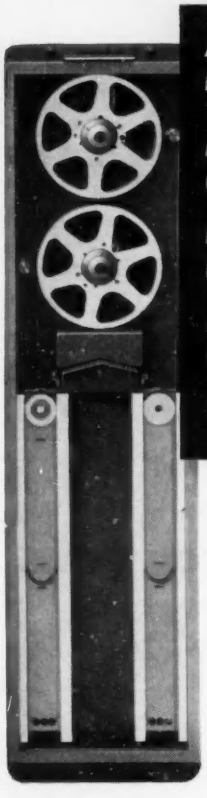
SIGMA INSTRUMENTS, Inc.

69 Pearl Street, So. Braintree, Boston 85, Mass.

DataReader

Model 546

A transport unit for high speed searching, reading and recording of data on magnetic tape.



Applications Include:

High-Speed Computing

Data Processing

Automatic Control

Telemetering

PERFORMANCE:

RAPID START—STOP—REVERSE—from stop to full speed in 6 milliseconds.

HIGH TAPE SPEED—optional single speed of 30, 40, 50, 60 or 75 in/sec.

TWO-DIRECTION SEARCH—either direction, automatically at full speed.

REMOTE OPERATION—forward, reverse, stop, rewind and selection of reading and writing.

VACUUM COLUMN TAPE CONTROL—provides strain-free tape feed over entire length of tape.

END-OF-TAPE SENSING—stops automatically at either end of tape.

RAPID REWIND—2400 ft. of ½" or ¾" tape in 3 minutes.

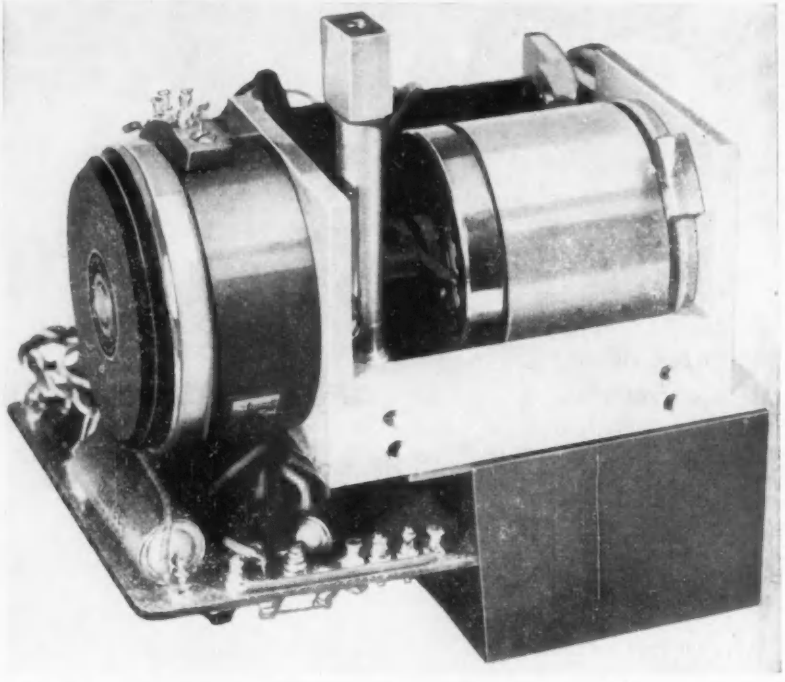
FOR FURTHER INFORMATION WRITE
ElectroData Corporation
Component Sales Division
460 No. Sierra Madre Villa
Pasadena 15, Calif.

ElectroData

An Affiliate of
CONSOLIDATED ENGINEERING CORPORATION OF PASADENA, CALIFORNIA
ElectroData Corporation maintains a nationwide sales and service organization.

NEW PRODUCTS

SERVO ELEMENTS



VOLTS CONVERTED to position through positional servo.

The above mechanism is essentially a miniature positional servo. It converts an input voltage into a shaft position through the use of a servo motor and follow-up potentiometer. The output shaft can be connected to such output transducers as synchros, potentiometers, and an-dig converters. Internally the Datran Model C104 consists of a two-stage voltage amplifier, a magnetic power-amplifier, a two phase servo motor, a gear train, and follow-up pot.

High accuracies despite normal line voltage variations are obtained through the use of the same power source for the input transducer and the servo.

Characteristics

Input resolution .....0.002 v rms
Input impedance .....1 megohm
Output rotation ....0 to 14,400 deg
Output speed .....full scale 0.5 sec
Power sources .....115 vac 400 cps
150 vdc at 7 ma
12.6 vac or dc at 300 ma
6.3 vac or dc at 600 ma
Size .....3 by 4 by 4 in.
Weight .....2¼ lb

Datran Engineering Corp., 3613 Aviation Blvd., Manhattan Beach, Calif.

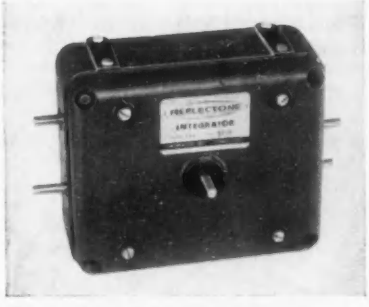
Circle No. 19 on reply card

MOTOR-GENERATOR: A combined Size 11 servo motor and drag cup generator has a 0.6 oz in. stall torque and top speed of 5,200 rpm, the motor driven by 115 vac 400 cps. The generator is excited by 115 vac 400 cps to yield 0.5 v per 1,000 rpm. Size 2½ by 1⅞ in. diam. *G-M Laboratories Inc., 4300 N. Knox Ave., Chicago 41, Ill.*

Circle No. 20 on reply card

LITTLE SYNCHRO: A new size 10 Synchro, less than 1 in. in diam for 26 volt 400 cycle systems, has a spread of angular error from 20 to 30 min. Type No. G's input impedance is 110 ohms per 65 deg when used as a transmitter or as a receiver. *John Oster Manufacturing Co., Avionic Div., 1 Main St., Racine, Wis.*

Circle No. 21 on reply card



TWO INTEGRATORS in one use same input shaft.

The ball and disc integrator above features two integrator sections driven by a common shaft. Output shaft speeds of the Model 246 are independently adjusted by separate control rods. *The Refectone Corp., Stamford, Conn.*

Characteristics

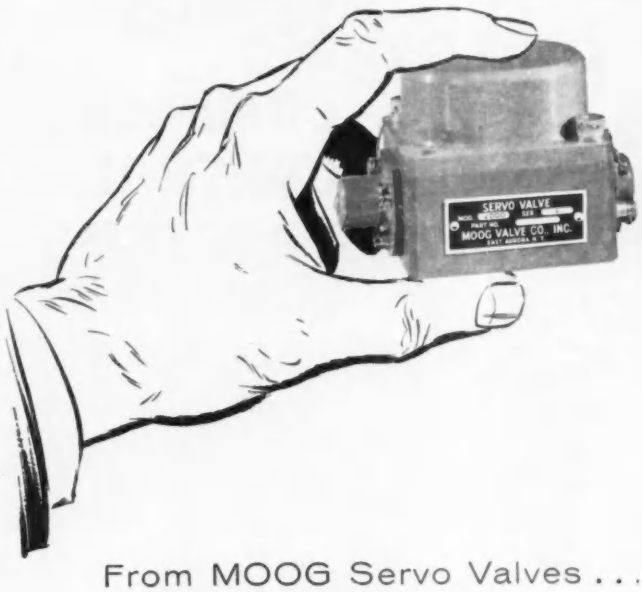
Input speed . . . . . .0 to 150 rpm
Unidirectional output . . . .0 to 0.8 times input
Reversible output 0 to 0.4 times input
Output torque . . . . . .to 16 oz in.
Error . . . . . .under 0.5 per cent
Case size . . . . . .3 by 6 by 7 in.

Circle No. 22 on reply card

SOME DETECTORS

MONITORS STRAIN GAGES of aircraft in flight.

Indicator display of strain-gage output is the function of this system. Input of 10 to 50 millivolts cause full scale indication. Linearity and repeatability are within 0.2 per cent. Intended for operation in flight, the instrument is self-balancing, and contains a pot, servomotor, gear train, comparator, amplifier, transmitting synchro, and indicator. Weight is under 10 lb. The system registers the



From MOOG Servo Valves . . .

Compactness

For control systems with space and weight limitations, Moog Servo Valves are exceptionally well suited because of their compactness. For instance, maximum dimensions of the new Model 2000 Dry Solenoid Servo Valve are 3.06 x 1.94 x 1.90 inches. Weight is 0.7 lbs.

Compactness is only one of the outstanding characteristics of these proportional type, four-way valves. They also are known for their sensitivity, linearity, reliability, and high dynamic performance. Equivalent time constants are as low as one and one half milliseconds from input differential current to output flow.

Performance of this magnitude makes possible control systems of high accuracy and response. Typical applications for these valves are in servo systems of advanced aircraft and guided missile flight controls, radar scanner actuation, contour following machine tools, and automatic packaging equipment.

Production models are designed to operate in hydraulic systems of from 1000 to 3000 PSI pressure. Rated output flow from 0.1 to 50.0 GPM, for control currents between 2.0 and 40.0 milliamperes as specified, are available in production units.

For details write for Bulletin 2000-2

MOOG VALVE CO., INC. PRONER AIRPORT EAST AURORA, N. Y.

CROSS OFF

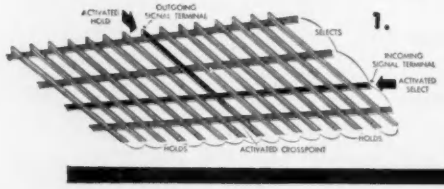
COMPLEX CONTROL PROBLEMS with

KELLOGG CROSSBAR SWITCHES

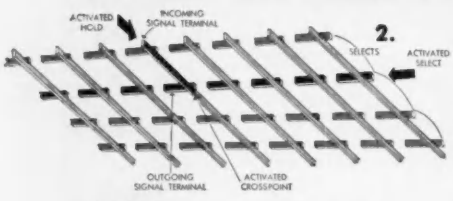
First used and overwhelmingly approved in the telephone industry, the KELLOGG Crossbar is one of the most versatile switch devices yet developed for industrial use. Simple in its operation — durable and dependable — it solves hundreds of multiple or complex switching problems at small cost.

It does away with the limitations inherent in relay trees. It provides connections as low as 25 to 30 milli-seconds for one or many input circuits to one or many output circuits. With Crossbar several switching operations may be done at the same time—any circuit may be held while other circuits are switched. Because Crossbar switch points move only a few thousandths of an inch, wear and maintenance are practically eliminated. Contacts are of paladium metal; gold can be provided.

The entire switch may be drawer mounted for easy inspection without disrupting service. The only wiring normally needed is to connect the input and output circuits. Shown below are the various types of electrical connections possible with KELLOGG Crossbar.



1. Drawing No. 1 illustrates the basic Crossbar principle which permits any of several incoming circuits to be connected to any of several output circuits. This type of switch can connect any of 60 circuits, 3 at a time, to any of 75.



2. Drawing No. 2 shows a means of switching one incoming circuit to many possible outgoing circuits—accomplished by removing every other vertical. Thus, instead of having one cable terminal at one end of the switch, each remaining vertical has its own cable connection. This type of switch can easily be adapted to switch one circuit to any of 936.

KELLOGG DIVISION OF IT&T

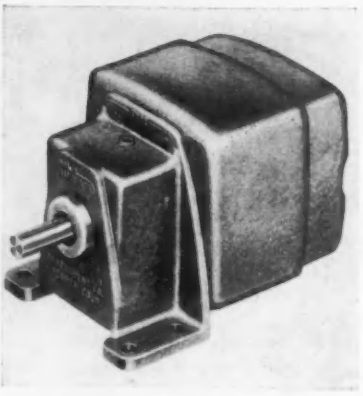
Write For This Free, Fact-Filled Booklet Today Dept. 72-J

KELLOGG SWITCHBOARD AND SUPPLY COMPANY
A Division of International Telephone and Telegraph Corporation
SALES OFFICES: 79 West Monroe Street, Chicago 3, Illinois

NEW PRODUCTS

output of a 350 ohm strain gage bridge as a per cent of full scale force input. *The Greenleaf Mfg. Co., 7814 Maplewood Industrial court, St. Louis 15, Mo.*

Circle No. 23 on reply card



TACHOMETER TRANSMITTER uses only switch and capacitor.

Inside the case of this velocity pickup is a two-pole double throw switch and a capacitor. The switch is operated by the input shaft in a way to move current via the capacitor (reversing the connection of the leads). The faster the shaft rotates, the faster the capacitor's charge can be moved along to a current-sensitive indicator. The maker claims that the indicating meter can be up to 1,000 feet away from transmitter. The Takeoff Head Series 32 requires little torque for its operation. Full scale speed ranges are from 100 to 5,000 rpm. *Metron Instrument Co., 432 Lincoln St., Denver 3, Colo.*

Circle No. 24 on reply card

PRESSURE SWITCHES: A line of pressure switches for aircraft and missiles that take 35 g vibration and are fitted for bulkhead mounting. *Southwestern Industries, 5880 Centinela Ave., Los Angeles 45, Calif.*

Circle No. 25 on reply card

PHOTOELECTRIC CONTROL: The Autotron Model F1A, for industrial light-beam detection, operates a DPDT relay with 8 amp (115 vac) contacts when exposed to a 5 ft-candle source of 0.125 sec. *Autotron Co., Box 722-AC, Danville, Ill.*

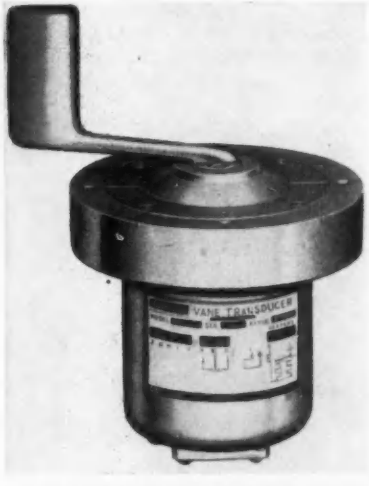
Circle No. 26 on reply card

PRESSURE TRANSDUCERS: A new series of pressure transducers are said to be relatively insensitive to vibration along any axis. They use unbonding strain gages and provide 20 millivolt full scale output with 5 vac or vdc excitation. Models sensing in ranges from 0 to 5 and from 0 to 150 psi, absolute, differential, or gage, are on hand. *Statham Laboratories, Inc., 12401 West Olympic Blvd., Los Angeles 65, Calif.*

Circle No. 27 on reply card

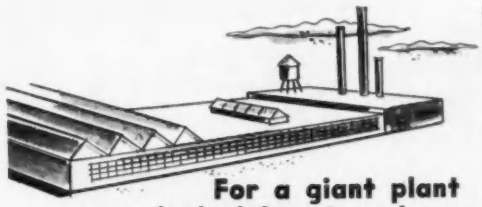
THERMOSTAT: Model A-1S-160, designed for economy and reliability, controls to ½ deg F through a 35 to 600 deg F range. Operation is by expansion of a 6 in. long rod, actuating a snap-action switch with 15 amp contacts. *Burling Instrument Co., 16 River Road, Chatham, N. J.*

Circle No. 28 on reply card

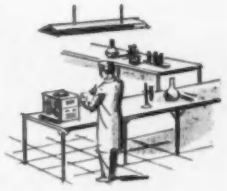


SLIPSTREAM TRANSDUCER signals damped angle-of-attack.

This instrument is mounted in an aircraft's slipstream. Its vane rotates a pot, synchro or other output device to provide angle-of-attack information. The maker claims that it is unique in its ability to "filter out" non-significant localized high-frequency airstream fluctuations. Natural frequency, damping, and response are completely independent of altitude and airspeed. Optimum performance at altitudes up to 60,000 ft and at speeds from Mach. 0.2 to 2 are claimed. It has a sensitivity of better than 0.06 deg at sea level. Its name: the Model 25116



For a giant plant or a single laboratory loop



From *all-seeing* SARA that monitors entire plant operations to efficient units for detecting hazardous gases in laboratory or plants, Taller & Cooper control equipment is designed to meet industry's exacting needs specifically, economically, automatically. Here are four instruments that were developed by Taller & Cooper, which are easily incorporated in existing plants to perform various control and supervisory functions.

TALLER & COOPER
MONITORING AND CONTROL EQUIPMENT

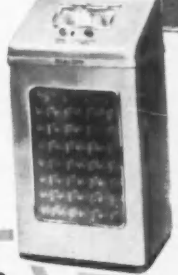
is engineered for automatic supervision

■ **SARA—Sequential Automatic Recorder and Annunciator** keeps an exact automatic log of as many as 500 separate plant operations continuously, automatically—and warns of any abnormal conditions.

■ **Supersensitive Analyzer for laboratory or control loop** detects hazardous gases as low as 5 parts per billion. In chemical control loop applications, it functions as analyzer, detector, monitor.

■ **Telemetering System for remote control of entire plant operation—** supervises multiple functions with only two wires. Affords complete plant control of 10, 16, 20, 32 or even 250 plant operations with the push of a button or switch.

■ **AUTOLOG automatically prints a permanent record of all plant operations.** Compact (48"x24"x15") AUTOLOG automatically supervises up to 50 trouble points, records occurrence of trouble conditions, as well as return-to-normal.



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75 FRONT ST., BROOKLYN 1, N. Y.

NEW
Arnold O. Beckman
MODEL F3
OXYGEN ANALYZER

with the meter on the door

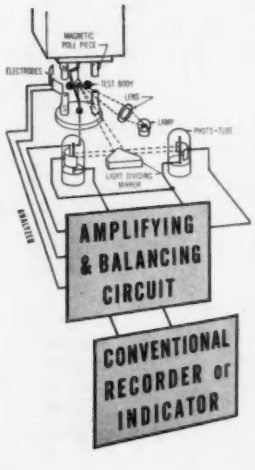
New convenience has been built into the well-known F3 Oxygen Analyzer . . . a meter on the door provides readings at the sampling point for making calibration checks, process changes, etc. In fact, complete analyzing, calibrating and indicating components are now incorporated into the single F3 unit—at no extra cost!

Use The Model F3

ON OPERATIONS LIKE THESE . . . TO MAKE SAVINGS LIKE THESE

COMBUSTION Boilers, Kilns, Direct-Fired Heaters, Stills, etc.	*Higher combustion efficiencies, at lower fuel costs*
PROCESSING Air Liquifraction . . . Processing Butadiene, Acetylene and Similar Gases	*Better product quality with minimum oxygen or air contamination*
PLANT SAFETY Hydrogenation, Hydrofining, Gas Compressors, Sulfur Grinding, etc.	*Control explosive atmospheres, reduce fire risks, minimize plant and personnel hazards*

Unique Operating Principle



The various applications highlighted above are only a few of the many ways Arnold O. Beckman Oxygen Analyzers—industry's great new profit builders—are being used by progressive operators to boost profits, cut costs.

These are the *only* oxygen analyzers that *continuously* measure process streams by an advanced magnetic principle that provides *direct physical measurement of the oxygen itself*—not of some secondary relationship.

Heart of the unit, as illustrated, is a dumbbell-shaped test body suspended in a magnetic field. Sample gas surrounding this test body causes it to rotate in the field, depending upon the oxygen content of the gas. The movement of a light beam, reflected by a small mirror on the test body, is measured by simple electronic circuits . . . and the result indicated directly on a conventional recorder or indicator. It's simple, positive, accurate!

No chemicals—filaments—catalysts cams—complicated mechanical parts!

Send for Helpful Free Literature which describes this unique operating principle in detail—explains its many advantages and applications. When writing, outline your particular operations—we'll gladly supply specific information.

Ask For Data File 16V-105

FEATURES OF THE F3

Many Ranges: Full scale ranges of 0-5%, 0-10%, 0-15% O_2 and higher.
Accuracy: 1% of full scale.
Multi-Ranges: Any instrument may be supplied with two or more ranges.

Note: For ranges narrower than 0-5% O_2 ask about the Model G2.

Arnold O. Beckman INC.
Instruments for Science and Industry
1020 MISSION STREET
SOUTH PASADENA, CALIFORNIA

NEW PRODUCTS

Aerodynamic Angle of Attack Transducer. G. M. Giannini & Co., Inc., 918 E. Green St., Pasadena 1, Calif.

Circle No. 29 on reply card

LONG RANGE PHOTOSWITCH: Set P4L features operation over distances of up to 100 ft and speeds of 600 operations per min. This is a complete, ready-to-use system. *Photoswitch Div., Electronics Corp. of America, 77 Broadway, Cambridge 42, Mass.*

Circle No. 30 on reply card

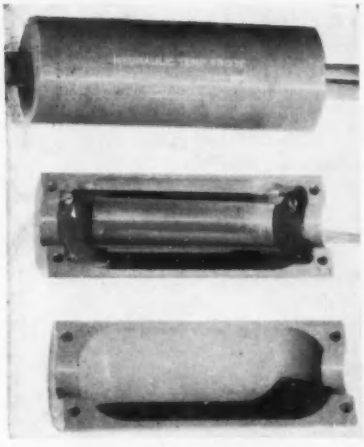
FLOW DETECTOR: Not much larger than a standard tee, the Model FI-200 closes or opens a circuit when liquid flow stops. Pipe sizes from ¼ in. to 3 in., operated by flows over 1.5 gpm., are available. Material is marine bronze and plastic. *The Gems Co., Newington, Conn.*

Circle No. 31 on reply card

TRANSIENT FORCES recorded internally on 35 mm film.

The instrument above, originally developed to record the forces produced on an opening parachute by its load, contains a 35 mm film recording mechanism that operates from 9 to 25 sec. It has a 25 cps time marker and a total of 18 in. of film. Forces within 4,000, 7,500, and 15,000 lb ranges can be handled by the device. It has a natural frequency of 1,000 cps. The Transient Force Recorder will soon be available for recording forces up to 60,000 lb. *Exline Engineering Co., 1636 E. Sixth St., Tulsa, Okla.*

Circle No. 32 on reply card

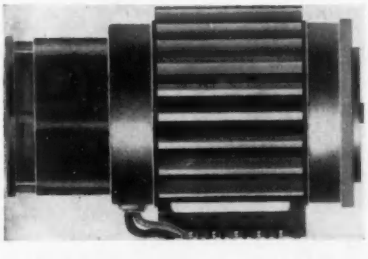


TEMPERATURE PROBE applied with no down time.

Getting at the temperature of hydraulic lines without even temporarily interrupting the system is the big feature of this temperature probe. It mounts outside the tubing. The case thermally isolates a long enough section of the line to provide an accurate indication of the temperature of fluid within. The Series 8000 Probe contains a 20,000 ohm temperature sensitive element, which, when used in a bridge circuit, provides relative high outputs for small temperature changes within the range of minus 100 to plus 500 deg F. *Arnoux Corp., Dept. CO-3, Box 34628, Los Angeles, Calif.*

Circle No. 33 on reply card

TORQUE AND ITS TRANSMISSION



MOTOR-GENERATOR delivers full thirty-five watts.

This machine adds a new power rating to the company's line of motors with built-in tachometers. It delivers 35 watts, can be stalled continuously

PRECISION COMPONENTS in Production

(shown ⅛ size)

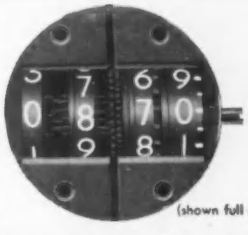
GYROS—3 Gyro Platforms, Floated Rate Integrating Gyros, Vertical, Free, Directional, Rate Gyros and Gyro operated Rate Switches—compact, lightweight, hermetically sealed.

(shown actual size)

SYNCHROS—Transmitters, Control Transformers, Resolvers, Repeaters, and Differentials in Bu Ord Sizes 15, 11 and 8. High accuracy and environmental resistance.

(shown ½ size)

SERVO MOTORS—High torque, low inertia Servo Motors, Servo Motor-Generators, Inertial and Viscous damped Servo Motors ¾" to 1¾" Diameter.



(shown full size)

MECHANICAL DEVICES

Counters, Electro-Mechanical Computers, Hermetic Rotary Seals, Aircraft Instruments and High Temperature Resistant, Chemically Inert, Machinable Ceramics.

(shown ¼ size)

ELECTRONICS—Miniature and subminiature Servo Amplifiers and Magnetic Amplifiers "potted" for convenience of installation and long life.

SYSTEMS

Aircraft Navigational Systems
Industrial Servo Systems
Servo Analog-to-Digital, Digital-to-Analog Converters
Electro-Hydraulic Servo Systems

Send For Technical Data Sheets

Bulletin giving physical and technical data on the various Kearfott Products will be sent on request. The Kearfott organization is available to assist in the development and manufacture of other precision components you may require.

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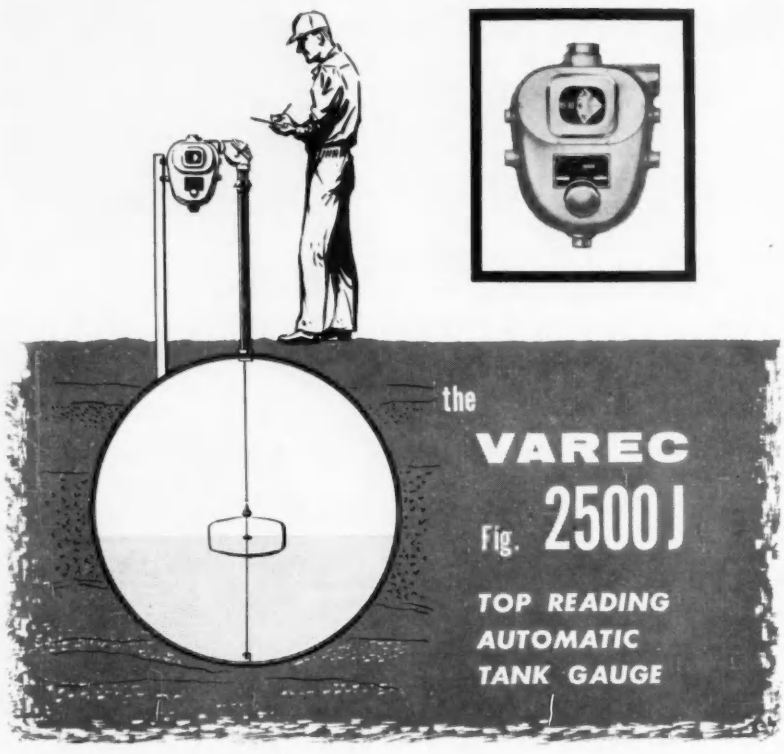
for
UNDERGROUND Tanks



The Figure No. 2500 J is an application of the dependable, field-tested, Figure No. 2500 Series Gaugehead. A Figure No. 2500, mounted in this manner equals or possibly exceeds the accuracy of a conventional cone-roof installation. Large, easily read dial has gravity compensator. Float and Neg'ator motor actuated, no counterweights are required. Low pressure model illustrated — also manufactured with flanged connections for working pressures up to 300 p.s.i.g.

Can be used with Varec Remote Gauger Transmitters without disturbing original installation. Also installation may be made on tanks in service.

For additional details contact your nearest Varec representative or write direct.

"Varec"

VAPOR RECOVERY SYSTEMS COMPANY
2820 North Alameda Street
Compton 1, California

961-11

Cable address: VAREC COMPTON Calif. (U.S.A.) All Codes

NEW PRODUCTS

with one phase of the motor excited at the rated voltage and frequency, and the tachometer of the unit can be adjusted so that in-phase, residual voltage may be kept at essentially zero. For magnetic amplifier application, 57½/57½-v control-phase windings are available. *Diehl Mfg. Co., Finderne Plant, Somerville, N. J.*

Characteristics

Reference phase voltage	115
Control phase voltage	115
Cycles	60
Poles	2
Phases	2
Rotor moment of acceleration	1.75 oz-in.
Min. locked torque	45 oz-in.
Free acceleration	10,600 rad/sec²
Tach output	6 v per 1,000 rpm
Tach linearity	1 per cent at 3,000 rpm

Circle No. 34 on reply card

CLUTCH-BRAKE facilitates sharp starts and stops.

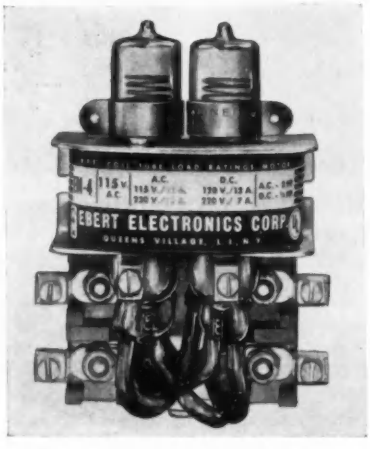
This servo-actuator, designed for high speed starting and stopping, is a pm motor with built-in clutch-brake. The motor is a standard Burton 1¼ in. diam 110 vdc Series 5000. When power is applied to the Model #5012-166 the clutch engages as the motor accelerates, and when power is released, the brake is energized. The maker provides the product with a variety of torques, output speeds, and operating voltages. *Burton Mfg. Co., 11201 W. Pico Blvd., Los Angeles 64, Calif.*

Circle No. 35 on reply card

RERATED MOTORS: A line of totally enclosed fan-cooled motors with ratings of from 7½ to 100 hp is announced. Fans are designed to operate equally well for either direction of rotation. *Century Electric Co., 1806 Pine St., St. Louis, Mo.*

Circle No. 36 on reply card

RELAYS AND SWITCHES



RELAY CONTACTS plunge into alumina-held mercury.

Improved materials and methods keynote redesigned mercury plunger relays. EM-4 (illustrated) and HD-4, the heavy-duty version, meet UL requirements. Contacts are hermetically sealed and function safely under explosive, corrosive, and outdoor conditions.

Design changes embodied in the extended line of mercury relays are tamper-proof, self-closing clamp and improved terminal block for simplified installation with vertical or horizontal compression-type load connectors. Alumina, the material of the mercury-holding cup, gives greater flexual strength, higher modulus of rupture, and handles higher in-rush currents.

Typical applications: Alarm and call systems, motor and valve controls, automation equipment, and control panels. *Ebert Electronics Corp., 212-26P Jamaica Avenue, Queens Village 28, N. Y.*

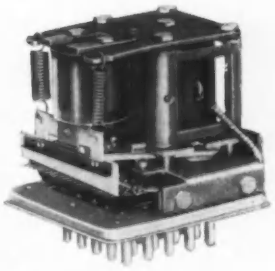
Characteristics

	EM-4	HD-4
Contact Rating		
(115 vac).....	35 amp	60 amp
(120 vdc).....	12	12
(220 vdc).....	7	7
Contact Arrangements		
	2PNO, 2PNC or 1PNO and 1PNC	2PNO, 2PNC or 1PNO and 1PNC

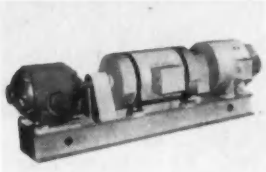
Coil Voltage: Coils are available for a variety of control voltages.

Circle No. 37 on reply card

Practical design engineers prefer REGOHM Regulators...

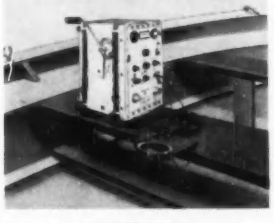


On Land... Continuous Power Generating Systems



REGOHM regulates the output voltage of this 5KW generating system within a 4% band, independent of load changes and other operating conditions. Used to power control and communications systems, these units must operate every hour of the year. REGOHM's long life and plug-in feature that simplifies replacement makes it a natural for this application.

On Sea... Hand-Cranked Generators



Fast-acting REGOHM maintains constant output voltage on hand-cranked generators powering portable lifeboat radios. Reliable over a wide temperature range, independent of speed of rotation and output loading, REGOHM delivers radio noise-free performance under severe operating conditions. No other equipment equals its size, and low cost advantages.

In the Air... Control Instrumentation

REGOHM regulates voltage of special control instrumentation in pilotless bombers where precise, reliable control is a *must.* A two-inch cube, weighing under a pound, REGOHM economizes on space and weight. System stabilization is assured by its built-in dashpot, adjustable to match the system's dynamic characteristics. No anti-hunt networks are needed.

Whether your equipment or control system operates on land, sea or in the air ...involves power supplies or communications and signal systems, instrumentation or lighting systems...look into the advantages of REGOHM regulation.

REGOHM

Contact Electric Regulator Corporation, 120 Pearl St., Norwalk, Conn. Our Engineering staff will help you design required circuitry...recommend the proper REGOHM type...calculate the resistor network...suggest design modifications for optimum performance...analyze final designs...assist in testing pre-production models...service your requirements. Write or call us today.

Electric Regulator Corporation
Norwalk, Connecticut Temple 8-4311

In the production of automatic systems for aircraft, missiles or other uses where high standards must be maintained a prime requisite is the *consistent* reliability of components.

If the accepted performance of relays for such applications is to be repeated exactly, lot after lot, the production must be controlled unit by unit through tests *more critical* than those usually applied in quality control. The slightest deviation from normal must be recorded and the information obtained used to guide the control of subsequent manufacture.

The production of North High Reliability Relays is controlled by constant repetition of the following rigorous tests.

A. ***Thermal Cycle Test;*** measuring operate and release values at specified voltages or currents within temperature variations from −65°C to +125°C.

B. ***Vibration on Most Vulnerable Axis Test;*** over 50,000 oscillations of 0.2 inches amplitude in 30 minutes.

C. ***Run-in Test;*** one thousand monitored operate-release cycles.

D. ***Service Test;*** including Sealing, Insulation Resistance, Dielectric Strength and Contact Resistance.

Test values are recorded and retained for each relay to provide essential information in a never-relaxing effort aimed at

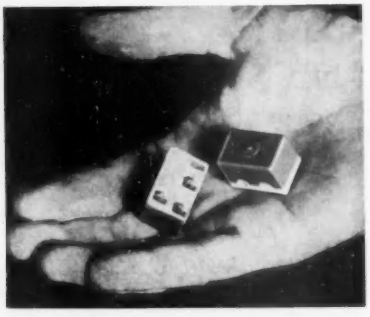
insuring reliability in . . .

NORTH RELAYS

NORTH ELECTRIC COMPANY

535 South Market Street, Galion, Ohio

NEW PRODUCTS



SNAP SWITCH adjustable to 0.0005 in. movement.

The Klixon K Series Sine Switch is sensitive to motions as fine as 0.0005 in. and can tolerate vibration of 500 cycles at 10 g while loaded to within 0.0002 in. of the actuation point. Movement differential as well as actuation point can be adjusted to meet a wide variety of application requirements. Life is 100,000 cycles minimum contacts 10 amp at 115 vac noninductive. Its size: $1\frac{1}{8}$ by $\frac{7}{8}$ by $\frac{11}{16}$ in. *Metals & Controls Corp., Spencer Thermostat Div., Attleboro, Mass.*

Circle No. 38 on reply card

DELAY RELAY does fast and slow work simultaneously.

The model NEL Agastat is a pneumatically-controlled delay relay that provides non-delayed actuation. The new model normally has an adjustable delay range of from 0.1 sec to over 10 min after energization for the main contacts. It provides a snap-action switch that operates the instant the coil of the relay is energized. Available for all ac and dc voltages, the contacts of the Agastat are rated for 15 amp. *A'G'A' div., Elastic Stop Nut Corp. of America, Elizabeth, N. J.*

Circle No. 39 on reply card

ROTARY SWITCH: The Type E-RVF rotary switch features driving mechanism and contact assembly enclosed for protection against dust, and six banks of 30 points. *North Electric Co., Galion, Ohio*

Circle No. 40 on reply card

SENSITIVE MERCURY RELAYS: Currents in the 3 micro-amp range operate the Micrelay, which handles up to 60 amps at 115 vac. The mercury-to-mercury contacts can be closed

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(64) PROGRAM CONTROL. Minneapolis-Honeywell Regulator Co. Industrial Div. Bulletin 1130, 22 pp. Describes types of program controllers, suggests some for specific applications, and covers several problems and considerations.

(65) PRINTED CIRCUITRY. National Vulcanized Fibre Co. Bulletin, 12 pp. Part I of this second edition of "Mechanize Your Wiring . . . With Copper-Clad Phenolite" covers the methods of producing printed circuits; Part II, specifications for copper-clad Phenolite laminated plastics.

(66) ALWAC III COMPUTER. Logistics Research, Inc. Brochure, 4 pp. Describes in detail this high-speed, low-cost, fully automatic electronic digital computer. Table of specifications included.

(67) FLOW COLORIMETER. Beckman Instruments, Inc., Beckman Div. Bulletin, 4 pp. Tells about new filter-type photometer that accurately records colorimetric measurements for continuous control.

(68) MAGNETIC TAPE RECORDERS. Cook Electric Co., Cook Laboratories Div. Project Digest PD-18, 16 pp. Illustrates and gives specs for recorders and systems designed for collecting flight data.

(69) HIGH VACUUM PUMPS. New York Air Brake Co., Kinney Mfg. Div. Catalog 425, 52 pp. This comprehensive reference work on vacuum engineering contains cutaway drawings, diagrams, graphs, performance curves, installation pictures, charts, and formulas.

(70) "AUTOMATION". The M. W. Kellogg Co. The Kelloggram, 16 pp. This colorful booklet describes Kellogg's approach to "control by instruments" and tells how it may affect the future of the petroleum and petro-chemical fields.

(71) MEASUREMENT. Engis Equipment Co., Data Sheet 5506. Gives specs and performance data on specialized instruments for precision measurement of angles and circular spacings. Chart form permits quick reference.

(72) BYRON JACKSON LINE. Byron Jackson Co., Electronic Div. Condensed catalog, 4 pp. Describes signal generators, VSWR indicators, incidental fm meters, and Vibrotron digital pressure gages and accessories.

(73) DIGITAL INSTRUMENTATION. G. M. Giannini & Co., Laboratory Apparatus Div. Bulletins 14300-1A, 14300-3, and 14300-2B, 4 pp. each. Cover applications of Giannini components, conversion kits, and the Model 14321 data handling system.

(74) QUICK DISCONNECT. Deutsch Co. Bulletin PD-1, 1 pg. Data sheet on internal locking mechanisms that need no safety wiring, spanners, strap wrenches, pipe pliers, or other tools.

(75) PHOTOELECTRIC CONTROLS. Electronics Corp. of America, Photoswitch Div. Bulletin, 20 pp. Contains specs for instruments used in high-speed counting, inspection and sorting, smoke control, and temperature measurement and control.

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(76) OPEN TYPE GEARED MOTOR. Barber-Colman Co., Small Motors Div. Bulletin F-6841, 4 pp. About a new quiet, rugged unit that has starting torques up to 75 lb-in. and gear ratios from 4:1 to 30,000:1. Three choices of base motors.

(77) RELAYS. Relay Sales, Catalog 1955-C6, 18 pp. Specs and prices pertaining to hundreds of standard relays now in stock.

(78) MID-CENTURY INSTRUMENTS. Mid-Century Instrumatic Corp. Bulletin, 14 pp. Covers five items in analog computing equipment: six-channel recorder, analog computer (portable), dc analog computer, six-channel electronic function generator, and am-fm electronic multiplier.

(79) ROTOTEST LABORATORIES. Bulletin, 4 pp. A brief description of this testing lab and its services, together with some pictures of the facilities.

(80) PHOTOELECTRONIC CONTROLS. The Autotron Co. Catalog, 16 pp. Application diagrams, specifications, and considerations in selecting light sources.

(81) PRECISION SWITCHES. The W. L. Maxson Corp., Unimax Div. Catalog 655, 24 pp. A very serviceable breakdown, starting with a pictorial index and running from general purpose to Joint Army-Navy (JAN) switches. Electrical ratings and definitions given at end.

(82) AUTOMATIC PROGRAMMING. Sperry Rand Corp., Remington Rand Div. Bulletin EL264, 4 pp. Discusses interpretive and compiling routines, respective programs, and three new developments: generalized programming, BIOR, and B-zero.

(83) GEAR TRAIN, CONTROL MOTORS. Transicoil Corp., Bulletin, 4 pp. Data on gear ratios available to designers who work against deadlines. Some are "immediate" (within a week), others "quick", and still others "custom-built."

(84) COMPUTERS AND COMPONENTS. Electronics Associates, Inc. Bulletin 31R-A6755, 16 pp., and assorted data sheets. The bulletin is confined chiefly to Computer Group 16-31R. The sheets touch on this, but give more space to components.

(85) READIX COMPUTER. J. B. Rea Co. Bulletin A-655, 12 pp. Developments in this digital computer are proceeding rapidly. Here's a comprehensive report on its operation and construction.

(86) EQUALIZERS, WAVE FILTERS. Aerovox Corp., Cinema Engineering Div. Catalog 12E, 16 pp. Discusses applications in sound and sound recording, reviewing some actual case histories, and gives specs for all items. Price list is inserted.

(87) SWITCHES AND GOVERNORS. Synchro-Start Products, Inc. Bulletin 504S, 8 pp. Contains drawings of and specs for overspeed and underspeed governors, and two- and three-element speed-sensitive switches. Available drives sketched.

(88) CONTROL COMPONENTS. Automatic Electric Sales Corp. Circular 1843, 4 pp. Matches each stepping switch, relay, and key switch with its illustration, function, and specifications. Result is a clever and succinct picture of AE's line.

(89) HIGH PRESSURE LINE. High Pressure Equipment Co. Catalog 2055, 26 pp. Describes this new company's high-pressure valves, adaptors, reactors, autoclaves, thermo-couplings, gages, fittings, and tubings.

(90) PRESSURE PILOT. Hammel-Dahl Co. Bulletin 110, 10 pp. No separate air gage is required for this pilot, which continuously indicates the pressure of the controlled process. Other features: direct or reverse action; proportional, on-off, or differential gap control.

(91) "ELECTROFLO" VALVE. Hays Mfg. Co. Folder 210, 8 pp. Describes a two-way, normally-closed solenoid valve that operates through line pressure. Takes pressures up to 150 psi. Continuous-duty solenoids are interchangeable.

(92) SYSTEMS ENGINEERING. Beckman Instruments, Inc., Berkeley Div. Bulletin, 12 pp. Covers data reduction, industrial control, information processing, and other industrial systems engineered by Berkeley's Industrial Systems Engineering Group.

(93) SPEED REDUCERS. Foote Bros. Gear & Machine Corp. Book, 40 pp. Gives details of new "Line-O-Power" units whose capacities range from fractional to 150 hp. Features permit coupling to motor in less space, easy changing of reduction ratios.

(94) DIFFERENTIAL PRESSURE TRANSMITTERS. Moore Products Co. Bulletin 1102, 8 pp. Gives design specs and performance data for flow-meter transmitters that convert motion to a 3-15 psig linear range of air pressures.

(95) GRADUATE COURSES. Case Institute of Technology. Leaflet, 6-pg. gatefold. Describes fall and spring graduate courses in instrumentation, servomechanisms, and process control.

(96) THERMO-VOLTAGE COMPENSATOR. Imported by Donald C. Seibert. AEG Bulletin, 4 pp. Tells about a new millivolt potentiometer that operates with continuous small drain from a standard cell by keeping current below level of saturation of the cell.

in 35 millisec. The Micrelay supplies its own operating voltage, or uses a 9 vdc or 12.5 vac external source. *Ebert Electronics Corp., 212-26P Jamaica Ave., Queens Village 28, N. Y.*

Circle No. 41 on reply card

OVERLOAD RELAY: An electronic relay sensitive to current differentials as small as 0.05 amp or voltage changes of 50 millivolts, can nevertheless handle 600 volts at 1,000 amp. Heart of the unit is a thyratron-controlled relay. When starting electric motors, 10-sec warm-up prevents operation from starting surge. *Morrow Products, Inc., 3339 Forbes St., Pittsburgh 13, Pa.*

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DELAY RELAYS: A proportional delayed reset after current interruption is a feature of a new line of hermetically sealed delay relays. Delays of from 5 sec to 1 hr and reset times of from 30 sec to 7½ min are available. The relays are built to government specs and can operate on dc or ac. *The A. W. Haydon Co., Waterbury, Conn.*

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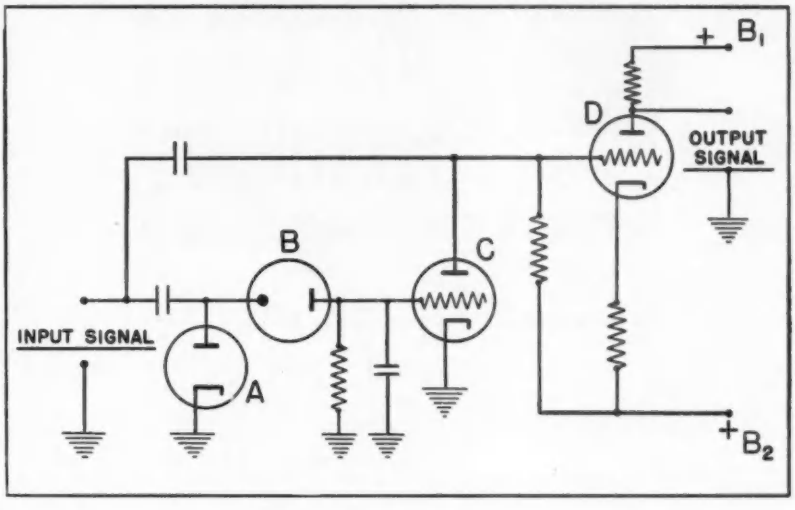
SINCE 1915 LEADERS IN AUTOMATIC CONTROL



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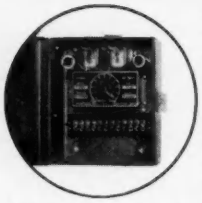

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amp, 115 vac, non-inductive.—*Farmer Electric Products Co., Inc., 21 Mossfield Rd., Waban, Mass.*

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VERSATILE SWITCH: A low-force, heavy duty limit switch utilizes a 5-in.-long aluminum rod, ⅛ in. in diam, as its actuating lever. 60 deg of overtravel is possible. Conduit type wiring is possible with the rugged aluminum housing. The contacts are rated for 10 amp at up to 480 v. *Micro Switch, Freeport, Ill.*

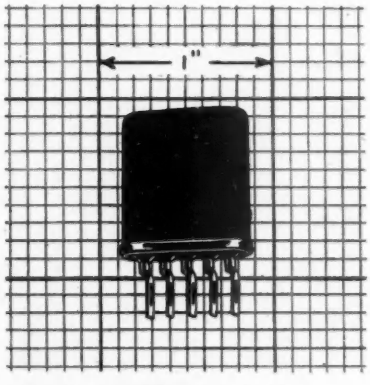
Circle No. 45 on reply card

MERCURY PUSHBUTTONS: Exceptionally high current capacities feature a line of pushbutton and selector type mercury-to-mercury switches. Bulletin 800 provides specifics. *Industrial Automation Corp, 2415 W. Montrose Ave., Chicago, Ill.*

Circle No. 46 on reply card

PLUG-IN RELAYS: Two types of relays, a general-purpose power model and a smaller type, each available with a variety of contact configurations, have been mounted on tube-type sockets. *Phillips Control Corp., Joliet, Ill.*

Circle No. 47 on reply card



RELAY'S SPEED credited to different design.

The above subminiature relay will follow applied ac up to 500 cps on its normally closed points, and up to 250 cps on both contacts. The design incorporates a permanent magnet in the armature structure, which is supplied for polarized or unpolarized operation. Standard pull-in is ½ watt and standard operating 1.1 watts although sensitivity to 50 milliwatts is possible by derating the contacts. The Luther M-1000 has ⅛ in. diam solid

silver or palladium contacts. *Luther Mfg. Co., 7312 Varna Ave., N. Hollywood, Calif.*

Characteristics

Coil .....550 ohm for 24 volts
Vibration .....10 g's to 500 cps std.
Contact life .....250,000 cycles
Speed .....2.0 millisec nominal

Circle No. 48 on reply card

SENSITIVE RELAY responds on photo cell output.

The low power requirements of a newly designed coil and magnetic structure enable a 1.5 cu in. relay to operate a single pole double throw contact arrangement on only 7 milliwatts. A cadmium sulfite photo cell delivers enough power to operate the relay without recourse to amplifiers. Models of the Series 23C are available with coil resistances of up to 10,000 ohms. *Kurman Electric Co., 35-18 37th Street, Long Island City, N. Y.*

Circle No. 49 on reply card

POWER SOURCES

NUT-SIZED diode designed to halt killowatts of power.

The silicon power diode above, not much bigger than a tea biscuit, will furnish enough dc to operate two 2 hp motors. They're being offered at present in ratings of 50, 100, 150, and 200 volts. The development of this small package with so much power-handling capability was the result of efforts to reduce the voltage drop and heat thereof. The new silicon diodes

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Circle No. 50 on reply card

BIAS SOURCE offered as small regulated power supply.

The above encapsulated package offers a regulated output for bias use in electronic circuitry. An input of 100 to 250 v, either polarity, yields either 10 or 20 v for a 1 or 10 megohm load respectively. Changes up to 42 per cent in input result in changes no greater than 10 per cent in output. Input resistance is over 6 megohms. Output ripple (1,500 cps) can be held down to 0.05 millivolts. Outputs up to 60 volts are possible. By connecting the input lead to B plus, the common lead to the plate of one tube, and the output lead to the grid of the following stage, the RB20 will act as a coupling battery. *Marine Electric Corp., 600 Fourth Ave., Brooklyn 15, N. Y.*

Circle No. 51 on reply card

HIGH, STABLE VOLTAGES: The N-401 offers continuously variable voltages from 500 to 1,800 positive at 5 ma. Voltages may be set to better than 10 ppm at any time. Ripple is less than 3 ppm, and stability is on the same order. *Hammer Electronics Co., Inc., P. O. Box 531, Princeton, N. J.*

Circle No. 52 on reply card

AC SOURCE: A line of ac power supplies is available with output regulation to within 2 per cent, and frequencies to within 0.5 to 0.001 per cent. Outputs ranging from milliwatts to kilowatts are accommodated with ac or dc input. *Behlman Engineering Co., 114 S. Hollywood Way, Burbank, Calif.*

Circle No. 53 on reply card

PACKAGE HYDRAULIC POWER: The Model .28-2MX power supply is an economical source suitable for laboratory for new equipment sub-chasses. It provides 28 vdc at 2 amps or less for control systems that can operate with 2.2 v ripple. *Dressen-Barnes Corp., 250 N. Vinedo Ave., Pasadena 8, Calif.*

Circle No. 54 on reply card

STRAIN GAGE POWER SUPPLY: Less than 1 millivolt ripple outfits a new magnetic-circuit power supply for use in place of storage batteries as a current source for strain gages. Regulation, to within 0.1 per cent, is continuously adjustable from 5 to 15 v at 1 amp. *Eagle Instruments, Inc., 14757 Keswick St., Van Nuys, Calif.*

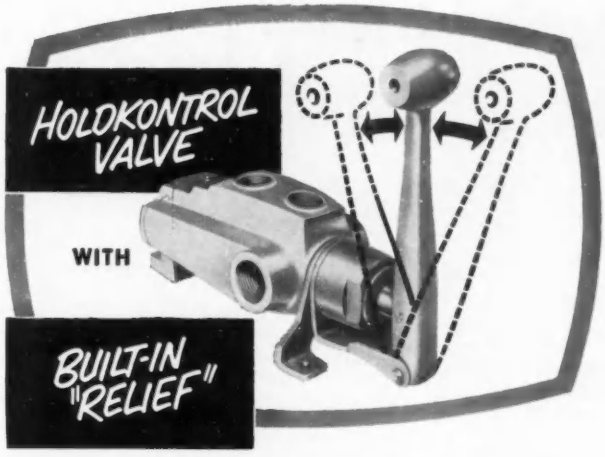
Circle No. 55 on reply card

HYDRAULIC POWER PACKAGE: A line of standardized hydraulic power units, in ratings of from ¾ to 20 hp include tanks complete with fittings and pipes, with the motor and pump mounted atop. The tanks' capacities range from 20 to 100 gallons. *The Rosaen Co., 24601 Harper Ave., St. Clair Shores, Mich.*

Circle No. 56 on reply card

TAPE CONTROL: A perforated, 140-channel tape controller for the Hillyer Automatic Locating and Drilling Machine makes the device fully automatic; the operator need only load and unload. The tool will drill any number of holes up to ½ in. diam on work up to 24 in. wide with location accuracy of a few ten thousandths. *Hillyer Instrument Co., Inc., 54 Lafayette St., N. Y., N. Y.*

Circle No. 57 on reply card



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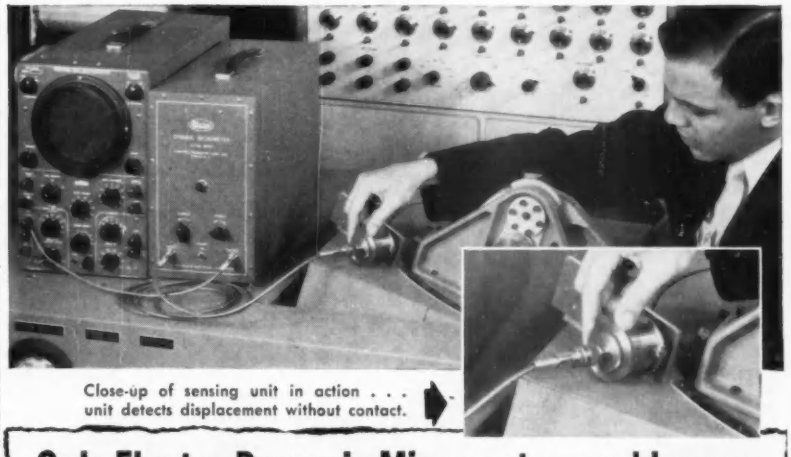

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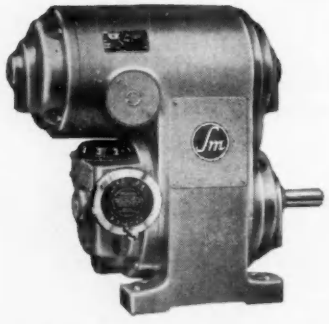

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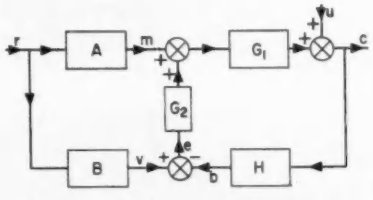
WHAT'S NEW ABSTRACTS

New Slant on Feedback

From "Conditional Feedback Systems—A New Approach to Feedback Control", an article by G. Lang and J. M. Ham, "Applications and Industry" (AIEE), July, 1955, pp 152-161.

The authors make the clear distinction between servo systems and regulator systems, and point out that in some control systems feedback is used solely to reduce influences of disturbances. Generally, feedback is applied to servos to obtain signal transmission and to regulators and servos to obtain disturbance reduction.

However, in conditional feedback systems, signal transmission becomes equivalent to an open-loop control system, the feedback overcoming only the effect of disturbances.



The figure shows the basic circuit of conditional feedback systems. When B equals AG_1H, and H equals 1, B represents the undisturbed transfer characteristics of the main transfer function. Therefore, B is called the reference model. Under these conditions, the authors prove that: 1) the ratio of the output to the input is simply AG_1—equivalent to open-loop control since there is no feedback factor, and 2) the ratio of the output to a disturbance equals $1/1 + G_1G_2H$, and thus disturbance can be reduced by increasing the gain within the limits of stability.

This new approach permits independent control of response to input signals and to disturbance signals. In fact, input-output response achieved this way can represent a great improvement over results with classical feedback, while reduction in disturbance will be at least as good as in the classical case.

The article includes a discussion of and design procedure for a positional servomechanism. Some of the results are worthy of mention: the conditional feedback offered a flatter and wider amplitude ratio in the frequency domain than did classical, single-loop feedback in a corresponding system; and the response to a unit step change in the time domain followed the input with a sharper rise and no overshoot.

The authors note that the systems they describe are the subject of patent action by Ferranti Electric, Ltd., Toronto, Canada.

Separate Screen Supplies

From "Electronic Voltage Regulators," National Bureau of Standards, Summary Technical Report, U. S. Department of Commerce, Washington 25, D. C.

Relatively simple, highly stabilized voltage regulators have been designed by S. Rubin of the National Bureau of Standards by adding a separate screen supply to beam power series tubes. Tubes with low ratios of screen-to-plate current are used with screen grid supplies that have semiconductor rectifiers. As a result, the series tubes of these circuits have slightly lower efficiency but much higher amplification factors than the low-mu triodes usual in voltage regulators. Several units can be interconnected to supply a number of voltages to a piece of equipment. In this case, the circuit can be simplified by energizing the screen grid of a lower-voltage regulator from the output of a higher-voltage regulator.

A voltage regulator usually consists of a series tube, a dc amplifier, and a source of reference voltage. The series tube is controlled by the dc amplifier and acts as a "variable resistor" connected between an unregulated source and a load. Signals representing the difference between a portion of a load voltage and a reference source are fed to the input of the dc amplifier, and the amplifier output voltage controls the "resistance" of the series tube.

Although the series tube should combine high efficiency with high amplification, an increase in one of these factors can generally mean a decrease in the other. Low-mu triodes like the 6AS7 are very efficient because they can pass a large amount of current with a small plate-cathode voltage drop. On the other hand, a triode-connected (screen grid tied to cathode through a small resistance)

beam power pentode has a higher amplification factor but requires a larger plate-cathode voltage drop for the same current and the same grid bias conditions. Adding a separate screen voltage source provides a unit that has a higher effective amplification factor than a triode-connected beam power tube with an efficiency that approaches that of a low-mu triode.

In a 300-volt regulated power supply, an input-voltage ripple of 1 v, plus a screen-voltage ripple of less than 0.5 v, plus line voltage change from minus ten percent to plus ten percent of nominal value, and a load variation from 25 percent of full load to full load, result in an output voltage variation of less than 0.2. The load current was 100 milliamps per tube.

Controlled Carbon Atmosphere . . .

From "Using Dew Points for Automatic Control of Heat Treatment Atmospheres", by Peter Trippe, Metalworking Production, England, May 13, 1955.

Direct detection and control of dew point facilitates regulation of carbon potential in heat treating atmospheres. A system for maintaining protective atmosphere in equilibrium with steel is described in this paper. It offers definite advantages in control of carburizing and carbo-nitriding furnaces.

An endothermic generator supplies the atmosphere in which parts are treated. The amount of carbon in the atmosphere must be kept in equilibrium with the carbon content of the part. Basically, the system modifies the ratio of air to gas to obtain the required dew points; the dew point, in turn, is a measure of the carbon in the atmosphere. Therefore, setting the dew point, calibrated in terms of per cent carbon, proportionally controls the carburetor and valve, thus maintaining the set point. Since the unit is automatic, changes in gas analysis during the day do not effect the carbon content of the atmosphere.

The sensing unit changes the electrical resistance of lithium chloride salt with absorption of moisture from the surrounding region. Current passing through the cell heats up the salt to a point of equilibrium. This temperature, now a measure of the dew point, operates the controller and recorder. The unit has a range of control from 0.30 to 1.5 per cent carbon potential.

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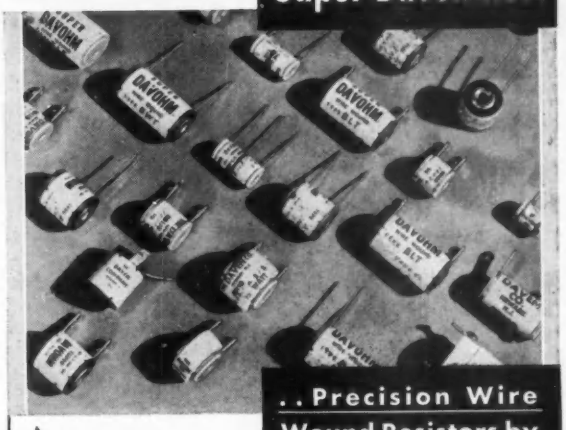

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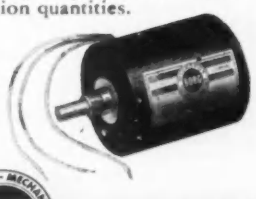

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ABSTRACTS

Thermocouple Dynamics

From "Response of Temperature Measuring Elements to Thermal Transients" by J. A. Clark, Assistant Professor, Massachusetts Institute of Technology, ASME Paper 55—SA—18.

Nomenclature

t—probe temperature, deg F
t_f—fluid temperature, deg F
h—heat transfer coefficient, Btu/hr per ft² per deg F
h_i—heat transfer coefficient in free convection at Θ_i, Btu/hr per ft² per deg F
θ—$t - t_f$, deg F
θ_i—$(t - t_f)$ at time = 0, deg F
T—time subsequent to immersion, hr
D—diam, ft
c_p—specific heat, Btu/lb$_n$ per deg F
V—volume, cu ft
A—surface area, sq ft
ρ—density, lb$_n$/ft³

This paper considers only those errors that result during temperature transients from thermal lags between the measuring element and a fluid. It reviews the literature on thermometric lag, discusses generalized theory, and then goes into solutions for probes with infinitely large factors of thermal conductivity, and sudden change in fluid temperature. It covers the transient response of a temperature probe of finite length and nonuniform diameter.

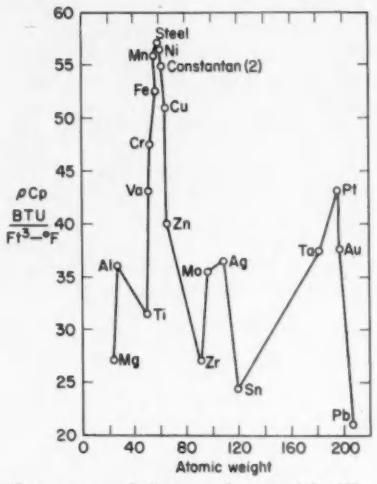
A simple but important case is that of a sudden change in t_f to some new value at time zero, after which it remains constant.

The response of the temperature-sensing element here can be written in terms of $\theta = t - t_f$, as

$$\frac{\Theta}{\Theta i} = e^{\frac{-hA}{\rho c_p V}\,T}$$

where θ_i equals $(t - t_f)_i$. This follows from the boundary condition that $\theta = \theta_i$ at $T = 0$. The above equation applies to both transient heating and cooling.

Rapid response is associated with large values of $hA/\rho c_p V$. The coefficient h depends upon the type of fluid and the Reynolds or Grashof number of the flow. The area-to-volume ratio A/V is a geometric factor selected at the discretion of the designer and frequently is taken as a compromise between response and durability. The product ρc_p depends on the material from which the temperature probe is made and can vary considerably. Values of ρc_p for several common materials at moderate temperatures are given in the first figure as a function of atomic weight. It is interesting



that many of the usual materials (Fe, steel, Ni, Cu) have the largest ρc_p and hence would have slower response than some of less common materials such as lead, tin, or magnesium.

While the assumption of a constant coefficient of heat transfer h is good for forced convection, it is not appropriate for natural or free convection. In this case h is a function of θ, and for horizontal circular rods can be written

$$h = c\left(\frac{\Theta}{D}\right)n$$

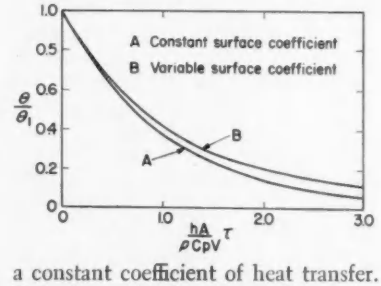
in which n and c may be treated as constants, c depending on the physical properties of the fluid.

Non-convection is easily treated when t_f is suddenly changed and then held constant. In this case

$$\frac{\Theta}{\Theta_i} = \left[1 + n\,\frac{h_i A}{\rho c_p V}\,T\right]^{-1/n}$$

is used for the boundary condition $\theta = \theta_i$ at $T = 0$; h_i corresponds to θ_i.

This result may be compared with



a constant coefficient of heat transfer. It is shown in the second figure as a function of $hAT/\rho c_p V$. The effect of free convection is seen to delay the response considerably.

NEW BOOKS

Higgins on Hydraulics . . .

HYDRAULICS SYSTEMS AND EQUIPMENT. *R. Hadekel, 5½ x 8¾ in., 224 pp. Published by Cambridge University Press, Cambridge, England, 1955, 18 shillings. Sold in the U.S.A. by Cambridge University Press, 32 East 57th Street, New York 22, N. Y.*

Essentially, this book is concerned with hydromechanical engineering and hydraulic machinery. To cover as divergent a quantity of material as possible without entangling the general reader in a mesh of specialized detail, the author opens with a broad view of the field of hydromechanics. He then gradually narrows attention to the domain of prime interest—major hydraulic power machines. There attention is focused solely on the hydraulic system: namely, on the circuit, control gear, and other hydraulic apparatus pertinent to functioning of the machine.

The first of the fourteen chapters is a broadly-based "Introduction", which advances the field of hydraulic machinery, certain properties of the currently used fluid medium, some useful equations of fluid mechanics, a concise account of the various basic elements of hydraulic systems (generator, transmission, control, and motor elements), and the symbols used on hydraulic circuit diagrams. This background is conjoined in a concise account of elementary hydraulic systems.

Chapter 2 discusses the basic "Principles of Control Gear", primarily the properties of valves and restrictors. Chapters 3 to 10 are concerned with the circuit problems in using the various hydraulic components of the system. The essential content of these chapters is indicated by the chapter headings: 3. Fundamental Principles of Circuits; 4. The Idling Problem; 5. Open Centre Systems and Allied Types; 6. Pilot and Electrical Control; 7. Automatic Sequence Systems; 8. Power Economy and Energy Storage; 9. Variable-Delivery Pumps and Continuous Motors; 10. Control of Load, Speed, and Position.

The remaining four chapters are largely concerned with treatment of equipment from the standpoint of details of design, manufacture, and installation. They are: 11. General Design Considerations; 12. Seals: Design of Jacks and Accumulators; 13. Valve Design; 14. Piping, Connections, Tanks, and Filters.

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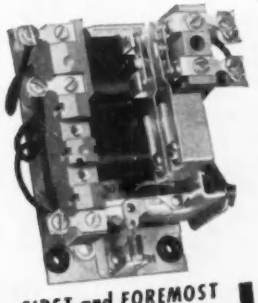

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"Index" complete the volume.

The author, a British engineer well-known both in Britain and the United States for his work on hydraulic machinery and hydraulic servomechanisms, writes with the authority gained from an intimate knowledge of—and substantial practice in—his subject. His style is excellent, his expression clear, his material up-to-date; and his treatment of the material on a level easily grasped by one who knows the rudiments of fluid mechanics. Because of these virtues and because no counterpart exists, the reviewer recommends a reading of this text (and also the author's [*Hydraulic*] *Displacement Pumps and Motors*, Sir Isaac Putnam and Sons, Ltd., London, England, 1951) to all control engineers who have occasion to work with hydraulic systems.

. . . on German Drive-Engineering . . .

ELEKTRONISCHE UND MAGNETISCHE STEUERUNGEN UND REGELUNGEN IN DER ANTRIEBSTECHNIK (Electronic and Magnetic Open-Loop and Closed-Loop Control in Drive-Engineering). *Edited by the Wissenschaftlichen Ausschuss des Verbandes Deutscher Elektrotechniker*, 7 x 9¾ *in.*, 124 *pp. Second improved edition. Published by the VDE-Verlag, Wuppertal and Berlin, Germany*, 1955.

This excellent work contains the same material as the first edition—the papers and discussions of the meeting on "New Electronic and Magnetic Open-Loop Controls in Drive-Engineering", which was held at Frankfurt-on-Main on May 16 and 17, 1952, under the auspices of the German Society of Electrical Engineers (VDE). Retaining the low price of the first edition (which, in considerable measure, accounted for the large demand for, and rapid exhaustion of, the first edition) necessitated keeping much of the same material. Accordingly, some interesting developments in drive-engineering of the past several years could not be included—though such inclusion would have been very desirable. However, the content of the first edition has been recast in the standard nomenclature and symbolism of the recently-adopted German standards DIN 19226 on control engineering. This recasting provides unification of content, which obviates a major shortcoming of the first edition—the diverse notation and symbolism employed by the individual authors.

The main text comprises seven papers and two sets of discussions. The central themes and relative lengths of the papers are clearly indicated by statement of (the translations of) the titles and the inclusive page numbers. 1. O. Mohr, "Fundamentals of electric and magnetic open-loop and closed-loop control" (pages 7-28). 2. J. Irtenkauf, "Electronic open-loop control for machine tools" (29-38). 3. W. Oppelt, "Various considerations in the choice of control devices in drive-engineering" (37-45). 4. A. Grün, "Electronic open-loop and closed-loop drives and transients on starting-up" (46-57). 5. H. Schrimer, "Open-loop rectifier drives in systems of high power output" (58-75). 6. Discussion, Group I: by Mohr, Schirmer, Grün, Vafiadis, Lebrecht, Kuhn,

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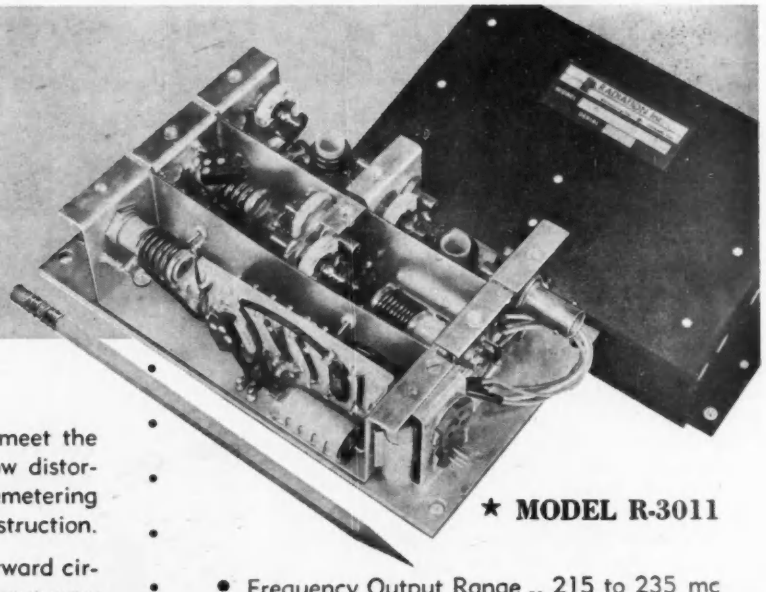

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Opitz, and Irtenkauf (76-81). 7. R. Jovy, "Examples illustrating electronic open-loop current-rectifier systems" (82-101). 8. Discussion, Group II: by Jovy and Treusch (102-103). 9. J. Förster, "Operating conditions in magnetic and electronic open-loop and closed-loop drives" (104-120).

A bibliography of seventeen books and 57 articles pertinent to the text (mostly in German) rounds out the volume.

All papers and discussions are by engineers well-known in the domain of German control engineering; they comprise an authoritative account of German industrial practice in drive-engineering.

This book should prove of interest to all engineers who want an over-all view of modern German practice in different fields of drive engineering—machine tools, paper-making machines, textile machines, etc.

. . . and on Non-Mathematical Cybernetics

MINDS AND MACHINES. W. Sluckin, lecturer in psychology, University of Durham, England, 4¾ x 7½ in., 223 pp. Published by Penguin Books, Ltd., Harmondsworth, Middlesex, England. 2 shillings. Available in U. S. through D. C. Heath & Co., Boston 16, Mass., approximately $.50.

This book is a nonmathematical, feedback-based explanation of the processes of control and communication in the human animal—a popularized account of cybernetics in the vein initiated by Norbert Wiener.

The brain is considered as a computing and deducing machine, the spinal cord as a means of conveying messages therefrom, and the various members and parts of the body as controlled elements. The prime thesis of interaction and control is that negative feedback actions underlie the working of the central nervous system. Thus, a considerable analogy exists between the structure and functioning of the human control system and engineering feedback control systems.

Chapter I, "Introduction" (pages 11-39), is a broadly-drawn outline of this analogy, which is examined in detail in succeeding chapters. Chapters II, "Computing and Other Machines" (40-68), and III, "Control and Communications" (69-87), delin-

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eate the operating principles of various types of computing, logic, and homeostatic machines, and briefly describe basic feedback control theory, showing them in typical engineering and homeostatic applications.

Chapter IV, "Mechanisms and Organisms" (88-107), concerns the similarities between mechanisms and organisms, outlining the thesis, developed over the centuries, that the human body and kindred living organisms function like machines. Chapter V, "The Working of the Central Nervous System" (108-128), and VI, "The Brain and Mental Functioning" (129-144), survey various pertinent developments and theories in neurophysiology regarding the physical basis of mental functioning, topics of considerable current interest in psychology.

The last chapters are, perhaps, best summarized in the author's own words: "Several general and specific developments in the theories of learning and problem-solving which have arisen out of cybernetic discussion are dealt with in Chapter VII ["Learning and Problem Solving" (145-170)]. Chapter VIII ["Thought Processes" (171-185)] and Chapter IX ["Adaptive Purposeful Behaviour" (186-210)] are devoted to the examination of new theories and concepts concerning mentality and behaviour, and to the analysis of the meaning and significance of what is being said and written on these subjects. Finally, Chapter X, ["Cybernetics, Philosophy of Mind, and Psychology" (202-218)] deals with the total effect of the impact of cybernetics upon what might be called the metaphysical climate of present day psychology."

A page of "Acknowledgements", an "Editorial Foreword", a carefully-compiled "Index", and a set of "Selected References" at the end of each chapter round out the text.

The author, a graduate in electrical engineering from the University of London and in psychology from Birbeck College, now lectures in psychology at the University of Durham. The reviewer found his book technically sound and well-integrated. He recommends it to all control engineers interested in a modern approach to the functioning of the control aspects of himself and his fellow humans—or, more simply, to anyone who desires to learn, painlessly, what comprises "human cybernetics".

Thomas J .Higgins
Dept. of Electrical Engineering
University of Wisconsin

WHAT'S AHEAD: MEETINGS

SEPTEMBER

American Institute of Chemical Engineers, Lake Placid National Meeting, Lake Placid Club, Lake Placid, N. Y.
Sept. 25-28

International Analogy Computation Meeting, Brussels, Belgium. Write P. Germain, University Libre de Bruxelles, So. av. Fr. Roosevelt, Brussels, Belgium.
Sept. 27-Oct. 1

American Institute of Electrical Engineers, Industrial Electronics Conference, Rackham Memorial Auditorium, Detroit, Mich.
Sept. 28-29

OCTOBER

National Electronics Conference, Hotel Sherman, Chicago, Ill.
Oct. 3-5

American Institute of Electrical Engineers, Fall General Meeting, Morrison Hotel, Chicago, Ill.
Oct. 3-7

Scientific Apparatus Makers Association, Mid-year Meeting, Recorder-Controller Section, Seaview Country Club, Absecon, N. J.
Oct. 11-14

Society of Automotive Engineers, Golden Anniversary Aeronautic Meeting, Aeronautic Production Forum and Aircraft Engineering Display, Hotel Statler, Los Angeles, Calif.
Oct. 11-15

American Standards Association and **National Bureau of Standards,** Sixth Annual Conference on Standards (includes tour of National Bureau of Standards), Sheraton Park Hotel, Washington, D. C.
Oct. 24-26

Instrument Society of America, Philadelphia Section, Symposium on "Automatic Control Loops—Electronic or Pneumatic?" Penn Sherwood Hotel, Philadelphia, Pa.
Oct. 28-29

NOVEMBER

Stanford Research Institute, World Symposium on Applied Solar Energy, Westward Ho Hotel, Phoenix, Arizona. Nov. 1-5

Institute of Radio Engineers, Association for Computing Machinery, and American Institute of Electrical Engineers, Eastern Joint Computer Conference and Exhibition, Hotel Statler, Boston.
Nov. 7-9

American Society of Mechanical Engineers, Diamond Jubilee Annual Meeting, Conrad Hilton and Sheraton-Blackstone Hotels, Chicago, Ill.
Nov. 13-18

Second International Automation Exposition, Navy Pier, Chicago, Ill.
Nov. 14-17

American Institute of Chemical Engineers, Annual Meeting, Statler Hotel, Detroit, Mich.
Nov. 27-30

Institute of Radio Engineers, Professional Group on Instrumentation, Conference and Exhibit, "Data Handling," Atlanta Biltmore Hotel, Atlanta, Ga.
Nov. 28-30

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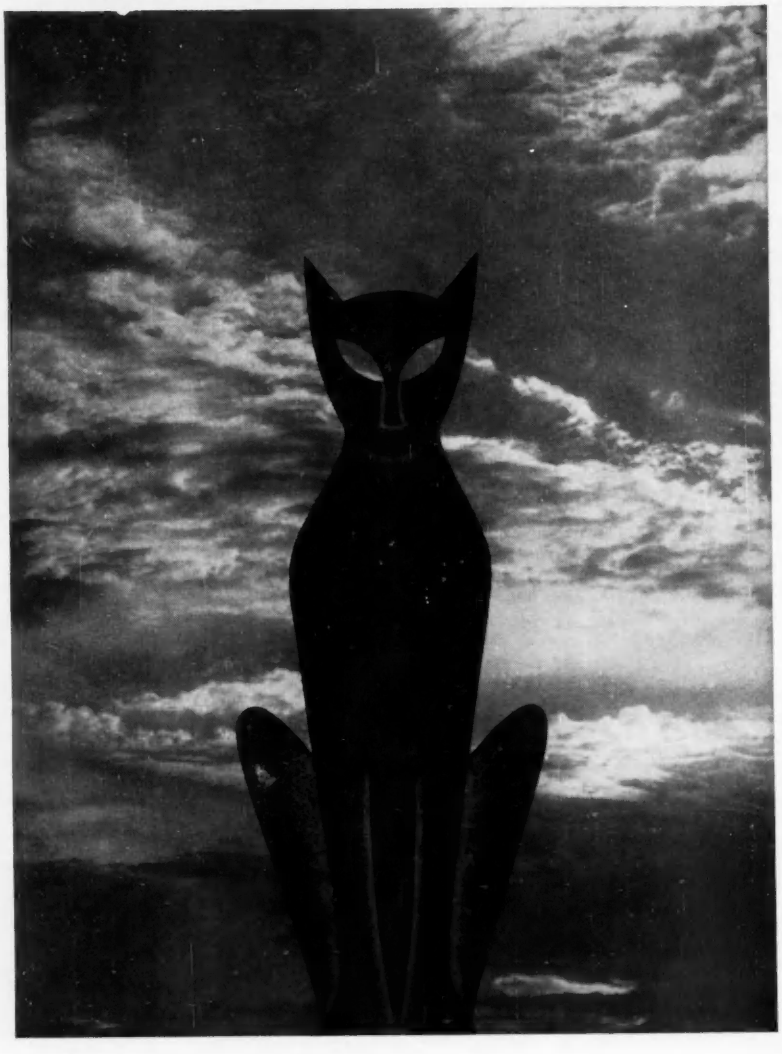

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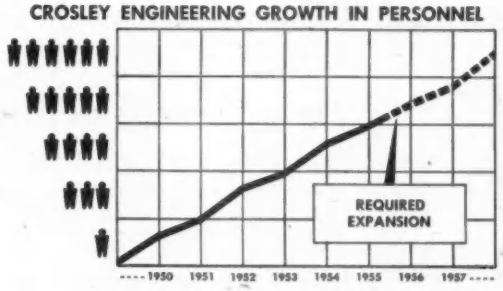

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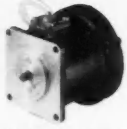

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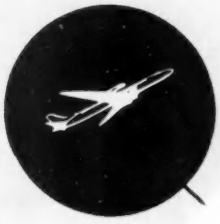
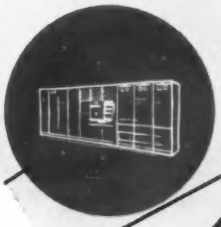
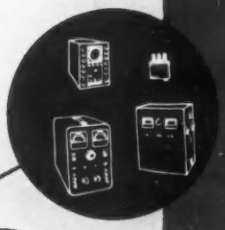
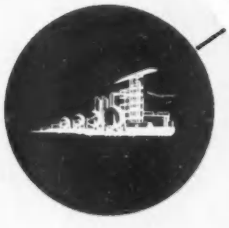
CONTROL TRANSMITTER Equipment (Used or Surplus New) For Sale 128









where
stability is a must . . .

TIC®

PRECISION TRIMMER POTENTIOMETERS

small..compact..precise

Engineered to the high standards of TIC Quality . . . a familiar standard of comparison. Environmental tested for MIL-E-5272A. TIC's Trimmer Potentiometers may be used as adjustable resistors or voltage dividers.

for

- **Adjusting scale factors of functions basically derived by other potentiometers**
- **Pinpointing circuit values of voltage, current, or resistance**
- **Balancing adjustments**
- **Critical magnetic or electric bias**
- **Padding or fixed reference circuits**
- **Establishing critical threshold voltages**
- **Fixed gain adjustments**
- **Compensation for variable parameters**

RV1/2 SUBMINIATURE TRIMMER

- ½" diameter, threaded bushing mounting, stainless steel case
- Dissipation: 1.5 watts at 25°C
- Resistance values: 50 ohms to 15K
- Temperature Range: −55°C to +80°C

RV7/8 MINIATURE TRIMMER

- ⅞" diameter, threaded bushing mounting, aluminum cup construction
- Dissipation: 2.0 watts at 25°C
- Resistance values: 50 ohms to 15K
- Temperature range: −55°C to +80°C

RFT SUBMINIATURE METLFILM TRIMMER

- 13/32" x .400 x 1 21/64", rectangular case, 2 screw eyelet mount, 25 turn lead screw adjustment
- Size permits stacking 7 per square inch
- Infinite resolution
- Dissipation: 0.5 watts at 40°C
- Resistance values: 50 ohms to 25K
- Temperature range: −55°C to +125°C

RVH1 HIGH TEMPERATURE TRIMMER

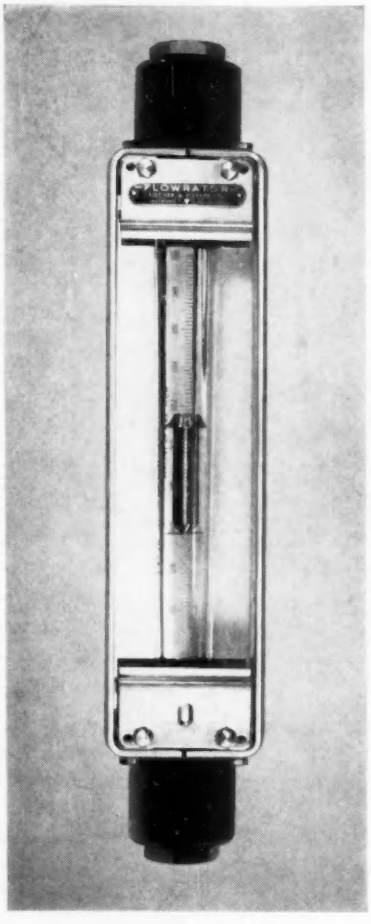
- 1" diameter, threaded bushing mounting, aluminum cup construction
- Dissipation: 2 watts at 25°C, 0.5w at +130°C
- Resistance values: 100 ohms to 5K
- Temperature range: −55°C to +145°C

For further information regarding your trimmer requirements, TIC invites your inquiries.

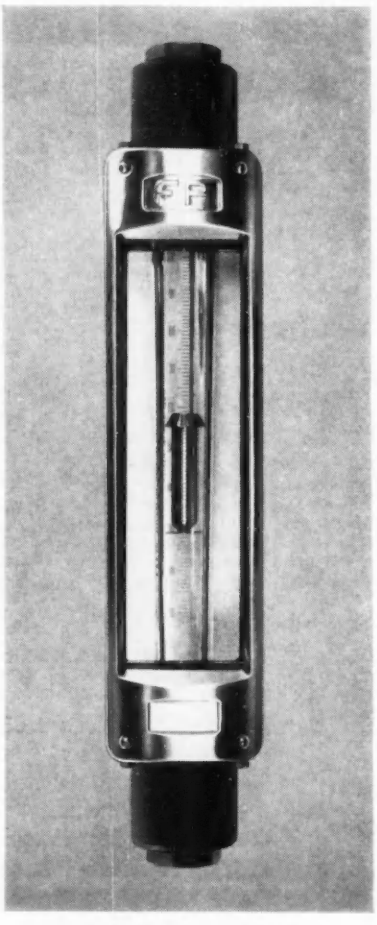
TECHNOLOGY INSTRUMENT CORP.

523 MAIN ST., ACTON, MASS. COlonial 3-7711
West Coast Mail Address P.O. Box 3941 North Hollywood, Calif. POplar 5-8620

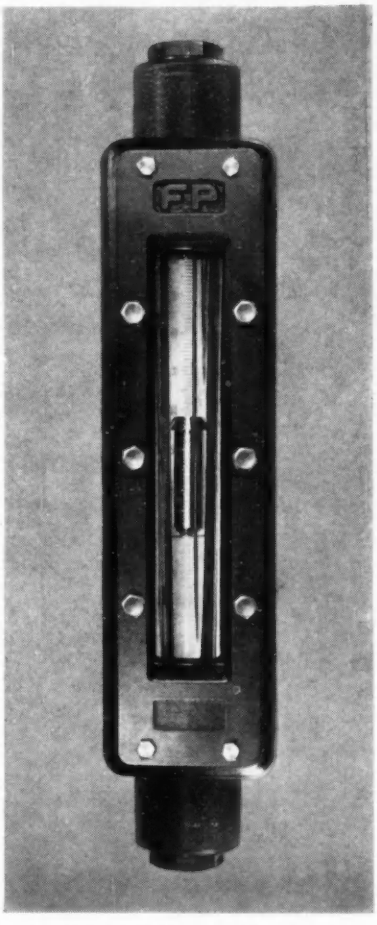
FP *complete process instrumentation*



SIDE PLATE FLOWRATOR METER



ENCLOSED FLOWRATOR METER



PRESSURE SEALED FLOWRATOR METER

A proven veteran with greater strength and a new dress uniform

Fischer & Porter's New 1700 Series Flowrator Meter

F&P has taken its proven 700 Series Flowrator Meter, kept the inherent good features, increased its strength and flexibility, and presented it in a new modern case. This improved instrument, the 1700 Series Flowrator Meter, retains the same over-all dimensions, the same proven universal end fittings, the same wide selection of interchangeable tube float and packing combinations. This permits immediate substitutions for any existing 700 Series meter installations without costly pipe changes.

These are the added features—

- Basic design allows for 3 types of construction from same frame
- Sturdier and safer construction
- Greater visibility of the meter (over 100% more vision)
- Built-in panel mounting fittings
- Stainless steel enclosure
- Built-in safety features

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Measuring, recording and controlling instruments
Centralized control systems
Data reduction and automation systems
Chlorination equipment
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